Mineral Development Division
Department of Mines and Energy
Government of Newfoundland and Labrador

GEOLOGY OF THE BAINE HARBOUR (1M/7) AND POINT ENRAGEE (1M/6) MAP AREAS, SOUTHEASTERN NEWFOUNDLAND

by

S.J. O'Brien and S.W. Taylor
Report 83-5

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GEOLOGY OF THE BAINE HARBOUR (1M/7)

AND POINT ENRAGÉE (1M/6) MAP AREAS,

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ABSTRACT

The Baine Harbour and Point Enragée map areas of the Burin Peninsula of Newfoundland are underlain by Late Proterozoic and Early Paleozoic rocks belonging to the Avalon tectonostratigraphic zone of the Appalachian Orogen. The areas are underlain by three major groups of regional stratigraphic extent. The Burin Group consists of oceanic volcanic rocks that have been dated isotopically at 763±2 Ma (Krogh, 1982). The Marystown Group, interpreted as unconformably overlying the Burin Group, has been dated at 608±25 Ma (Dallmeyer, 1981). It consists mainly of extensive dominantly subaerial volcanic and related clastic deposits. It is intruded by a suite of predominately hornblende-biotite-bearing granites. The Musgravetown Group consists of a shallowing upward flyschoid clastic succession. It is interpreted to overlie the Marystown and Burin Groups. A Lower Cambrian succession conformably overlies the Musgravetown Group; it is dominated by shallow marine clastics and carbonates and contains a basal orthoquartzite-rich unit (Random Formation).

The main deformational event affected both Proterozoic and Paleozoic rocks; isotopic evidence indicates that deformation occurred during Acadian orogenesis. However, evidence of a local Proterozoic deformation is preserved in rare deformed detritus in conglomerates of the Musgravetown Group. The Acadian deformation was inhomogeneous and resulted in extensive northwest-southeast shortening across the region. Regional metamorphism occurred in subgreenschist to midgreenschist facies conditions.

Although known mineral occurrences are few, the region holds untested potential for gold and base metal mineralization.

The Proterozoic to Earliest Paleozoic evolution of the area is interpreted in terms of a larger model of pre-Appalachian tectonics that is analogous in many respects to the largely intracratonic development of the Late Proterozoic Pan-African belts of North Africa. Limited separation of a sialic basement led to the local development of discontinuous tracts of circa 760 Ma oceanic crust. Continued rifting and subsequent closure of these "oceanic" basins ultimately led to the eruption of subaerial volcanic suites, granitoid plutonism, extensive faulting and the formation of Late Proterozoic sedimentary basins in the Avalon Zone of Newfoundland. The earliest Cambrian deposits of the region were formed during transgression of a shallow sea.

INTRODUCTION

The Baine Harbour (1M/7) and Point Enragée (1M/6) map areas constitute the central portion of the Burin Peninsula between North latitudes 47°15' and 47°30', and West longitudes 54°30' and 55°30' (Figure 1). Most communities in the area are accessible via roads from Route 11, whereas resettled villages may be reached only by boat. The villages of Southeast Bight and Petit Forte are serviced by weekly coastal boat service. The main road system serves as an adequate means of access for much of the study area, however, helicopter or fixed wing aircraft are necessary to expedite mapping in the central portions of the Point Enragée area. All of the coastline is accessible by small boat, given suitable weather conditions.

Surficial and Glacial Geology

The study area forms a part of the "Atlantic Upland" physiographic subdivision (Twenhofel and MacClintock, 1940), consisting of a peneplain surface represented by monadnocks that attain a maximum elevation of 325 m. A second erosional surface at 250 m to 255 m relates to the High Valley Peneplain surface of the Avalon Peninsula (Twenhofel and MacClintock, 1940). The peneplain surfaces are dissected by valleys created along zones of weakness within bedrock.

Overburden is usually confined to valley areas and consists of: (a) varying thicknesses of glacial till, most extensive in some of the larger valley floors; (b) an area of rib moraine (till ridges) located in the north-central part of the map area, southeast of St. Bernard's, that may locally attain thicknesses in excess of 30 m; (c) glaciofluvial or fluvial deposits associated with present drainage systems in the larger valleys; (d) esker deposits located mainly in the Bluff Head to Garnish Blue Hills area; and (e) raised marine terraces and associated raised beach and glaciomarine deposits along the coastline of the western part of the study area, and to a lesser extent along the Placentia Bay coast, particularly Flat Islands and Broad Cove Head.

The area was glaciated during two separate glacial events (Vanderveer, 1977). The first consisted of a movement of ice south to southeast across the study area from an ice centre located in the interior of the island of Newfoundland. Following a nonglacial interval, a second flow of ice to the north and northwest, from a source centred offshore in Placentia Bay, affected the area.

The orientation of rib moraine in the north-central part of the map area (Vanderveer, personal communication, 1979) and in the area west and northeast of Bay L'Argent (1M/10), plus the presence of drumlinoid features northeast of the map area indicate that ice centred in the interior of the island was the dominant transport and depositional agent. These features also suggest that if this part of the Burin Peninsula were later overrun by ice from the southeast or had supported a late remnant ice cap, then the effects of later ice movements in the north-central parts of the map area were minimal.

Previous Work

With the exception of reconnaissance by Dale (1927) and detailed mapping of Oderin Island by Williamson (1956), there is no record of geological investigation in the study area prior to the 1:250,000 reconnaissance work of Anderson (1965). The only other mapping was carried out during regional exploration surveys by Radex Minerals, Serem Ltée. (Schrijver, 1972, 1973), and Allied Chemicals Corporation (e.g. Fitzpatrick and House, 1973).

Present Investigation

This report embodies the preliminary results of field work and related

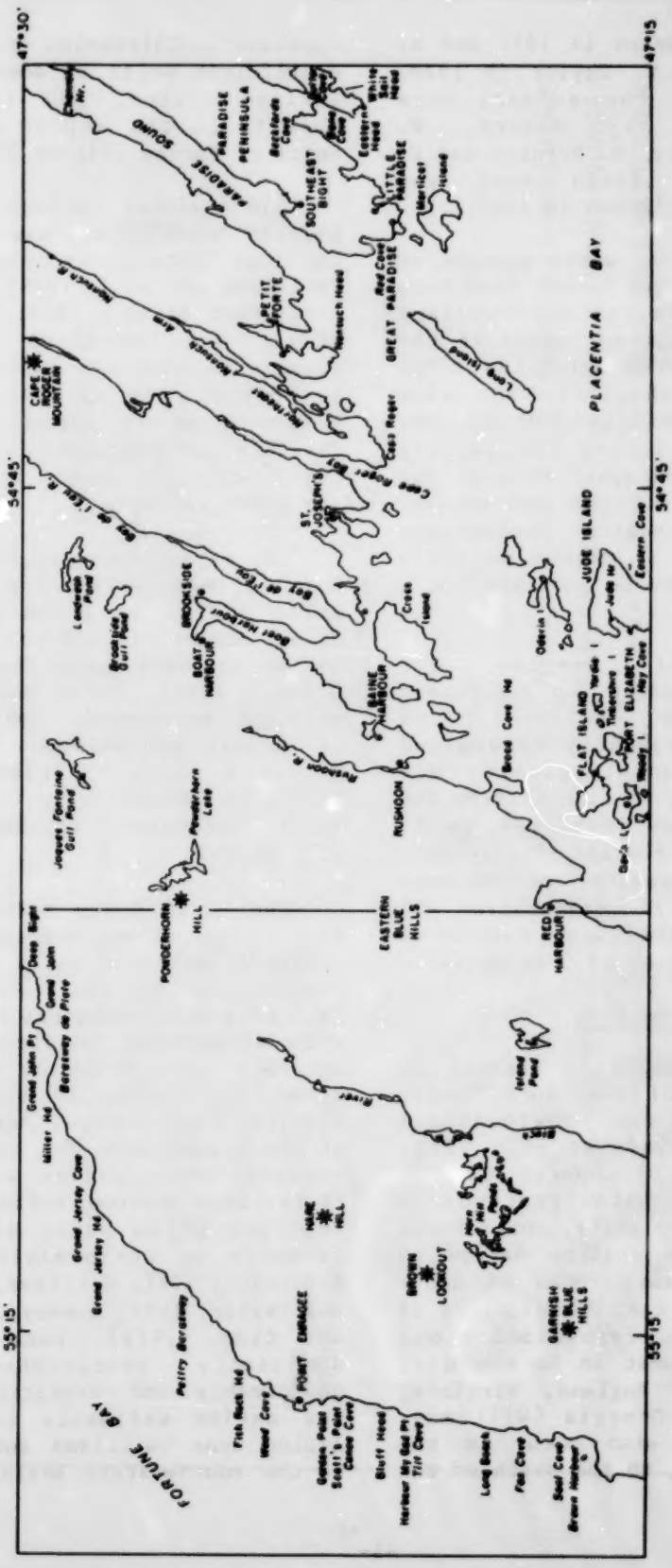


Figure 1: Location of place names referred to in text.

studies by S.J. O'Brien in 1977 and by S.J. O'Brien and S.W. Taylor in 1978. During this time, the authors were capably assisted by Messrs. W. Ashbourne, P. Bradley, B. Brinson and E. Wheaton. Limited field work was undertaken by S.J. O'Brien in 1980.

Field observations were recorded on aerial photographs and Forest Inventory maps available from the Newfoundland Department of Forests and Lands at the scale of 1:15,840 from which the final 1:50,000 scale geological maps were prepared. Approximately 200 of the samples collected during the mapping were used for petrographic studies and whole rock chemical analyses and assays. Results of the geochemical studies are to be presented in a memoir on Burin Peninsula geology, to be published at a later date.

Collection of samples for geochronological studies was supervised by R.D. Dallmeyer, University of Georgia, who subsequently determined $^{40}Ar/^{39}Ar$ incremental-release age spectra. U/Pb dating of zircons from the Marystown Group was completed by R. Coum, University of Florida. Preliminary results of these studies are reviewed here; a more detailed presentation and discussion of data are published elsewhere (Dallmeyer et al., in press).

Regional Geological Setting

The Burin Peninsula is located in the western part of the much larger Avalon Zone of the Newfoundland Appalachians (Williams et al., 1972, 1974; Figure 2). Diagnostic of the Avalon Zone are Late Proterozoic volcanic, sedimentary and plutonic rocks locally overlain by shallow marine to terrestrial sedimentary rocks of Early to Middle Paleozoic age. Correlatives of the zone have been recognized along strike to the southwest in Nova Scotia, New Brunswick, New England, Virginia, the Carolinas and Georgia (Williams, 1978). Equivalents also occur in the British Caledonides, to the south of the Appalachian-Caledonian Orogen in several Pan-African belts adjacent to the West African craton, and in Proterozoic massifs in the Alpine and Hercynian belts of Europe (Figure 3).

The regional geology of the Avalon Zone in Newfoundland has been discussed in some detail by various authors (Williams et al., 1974; King et al., 1974; Rast et al., 1976; Taylor et al., 1979), and therefore only a brief summary is presented below. A simplified geological map of the Newfoundland Avalon Zone is shown in Figure 4. Possible stratigraphic correlations of the Proterozoic units across the zone are given in Table 1.

The oldest dated rocks in the Avalon Zone in Newfoundland are a sequence of mafic pillow lava and gabbro (Burin Group) occurring in a narrow fault block on the southern Burin Peninsula (Strong et al., 1975). Their relationship with adjacent Proterozoic sedimentary rocks is unclear and has been interpreted as either a fault (O'Brien and Taylor, 1979), an unconformity (Hiscott, 1981), or a conformable sequence (Strong et al., 1978b).

The Burin Group volcanism predates deposition of widespread, dominantly subaerial volcanic rocks throughout the Avalon Zone in the Late Proterozoic. Lack of geochronological control coupled with structural complexities prevent accurate correlation of the individual subaerial, dominantly bimodal volcanic massifs which outcrop across the width of the Avalon Zone. The contact of these volcanic rock bodies with overlying Proterozoic marine sediments has been interpreted as being either disconformable or conformable (Hughes and Brückner, 1971; Williams, 1971; O'Brien and Taylor, 1979; Hussey, 1979; Williams and King, 1979). Late Proterozoic, dominantly continental sediments conformably and gradationally overlie the marine sediments in the eastern Avalon Zone (Williams and King, 1979). In the southwestern Avalon Zone, marine

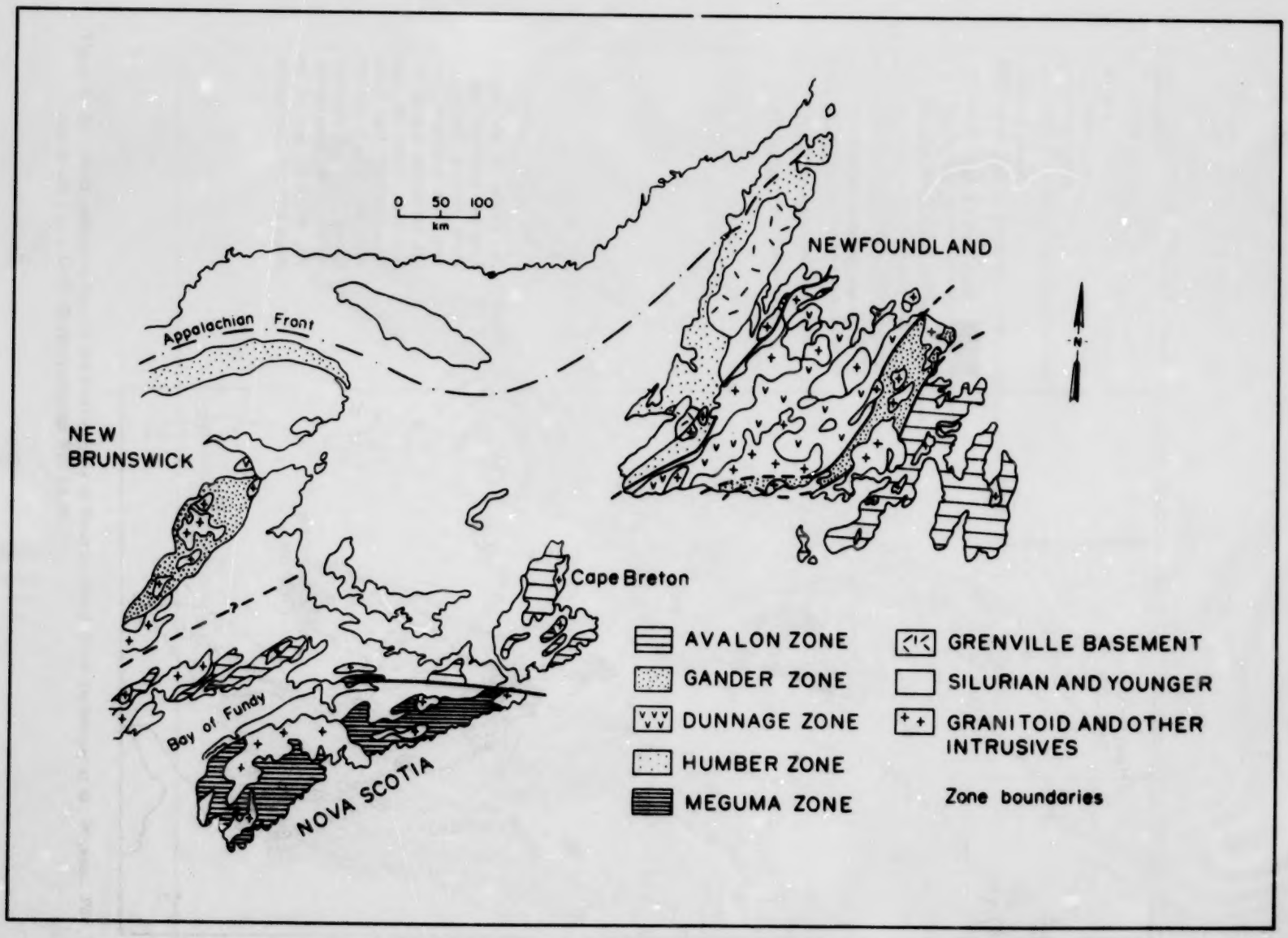


Figure 2: Tectonostratigraphic subdivisions of the Appalachian Orogen in Canada (after Williams, 1978 and O'Brien et al., in press).

Figure 3: Distribution of the Avalon Zone and associated rocks in North America, Europe and Africa. **GS**, Greenland Shield; **CO**, Caledonide Orogen; **HF**, Hercynian Front; **Nf**, Newfoundland; **NB**, New Brunswick; **NS**, Nova Scotia; **CP**, Coastal Plain; **AF**, Appalachian Front; **Ma**, Mauritanides; **PH**, Pharusian belt of the Hoggar Shield; **D**, Dahomeyian.

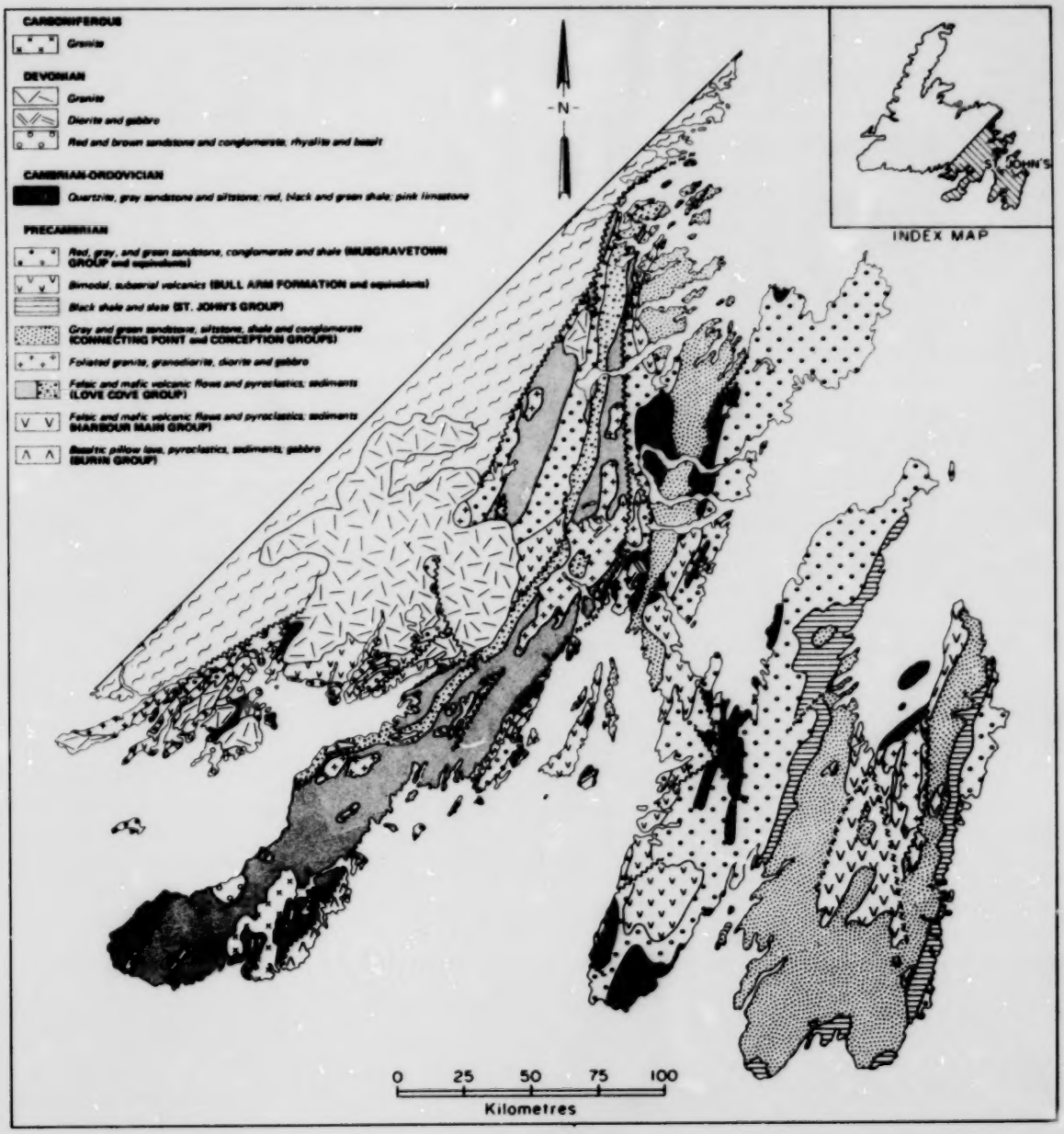

CARBONIFEROUS
Granite
DEVONIAN
Granite
Diorite and gabbro
Red and brown sandstone and conglomerate, rhyolite and basalt
CAMBRIAN-ORDOVICIAN
Quartzite, gray sandstone and siltstone; red, black and green shale; pink limestone
PRECAMBRIAN
Red, gray, and green sandstone, conglomerate and shale (MUSGRAVETOWN GROUP and equivalents)
Bimodal, subaerial volcanics (BULL ARM FORMATION and equivalents)
Black shale and slate (ST. JOHN'S GROUP)
Gray and green sandstone, siltstone, shale and conglomerate (CONNECTING POINT and CONCEPTION GROUPS)
Foliated granite, granodiorite, diorite and gabbro
Felsic and mafic volcanic flows and pyroclastics, sediments (LOVE COVE GROUP)
Felsic and mafic volcanic flows and pyroclastics, sediments (HARBOUR MAIN GROUP)
Basaltic pillow lava, pyroclastics, sediments, gabbro (BURIN GROUP)
N
INDEX MAP
0 25 50 75 100
Kilometres

Figure 4: Simplified geological map of the Avalon Zone in Newfoundland (from Dallmeyer et al., in press). PBF, Paradise Sound Fault; DHF, Dover-Hermitage Bay Fault.

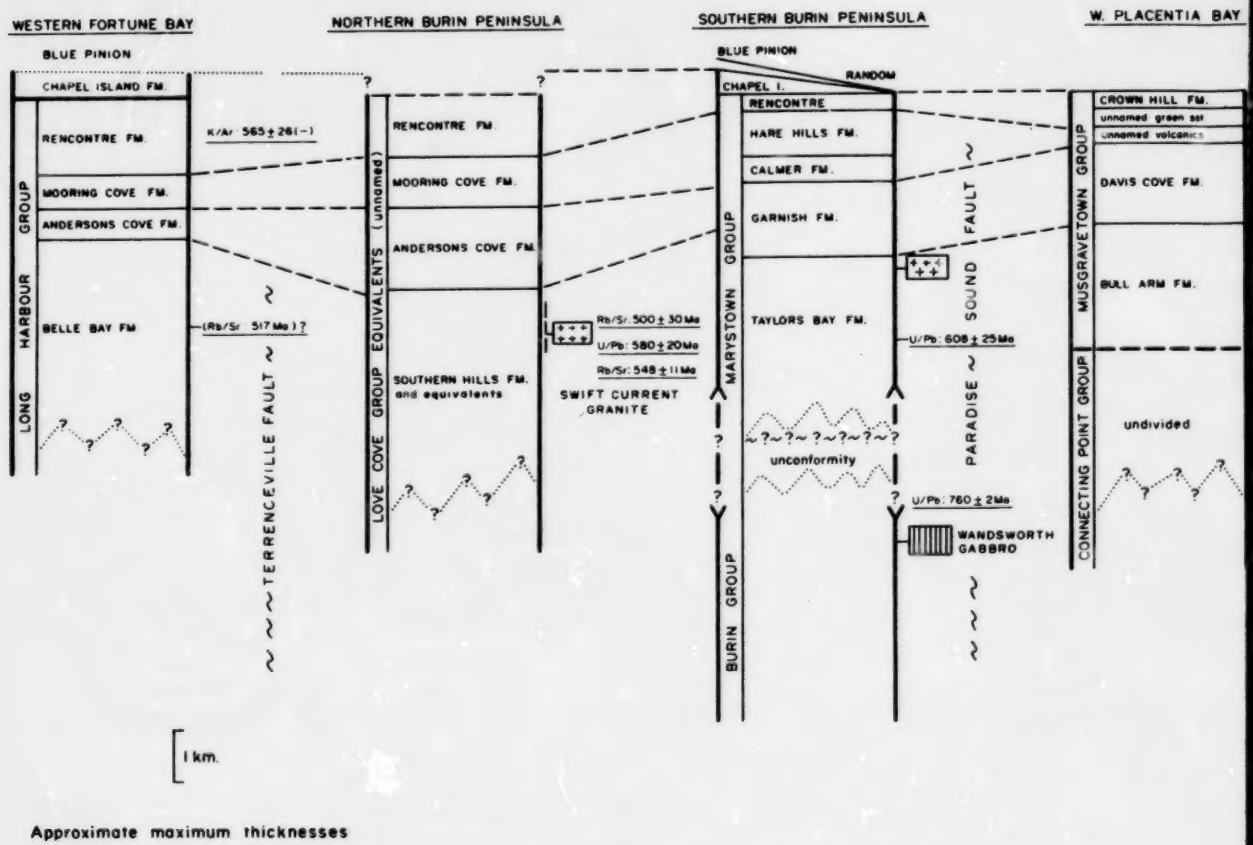
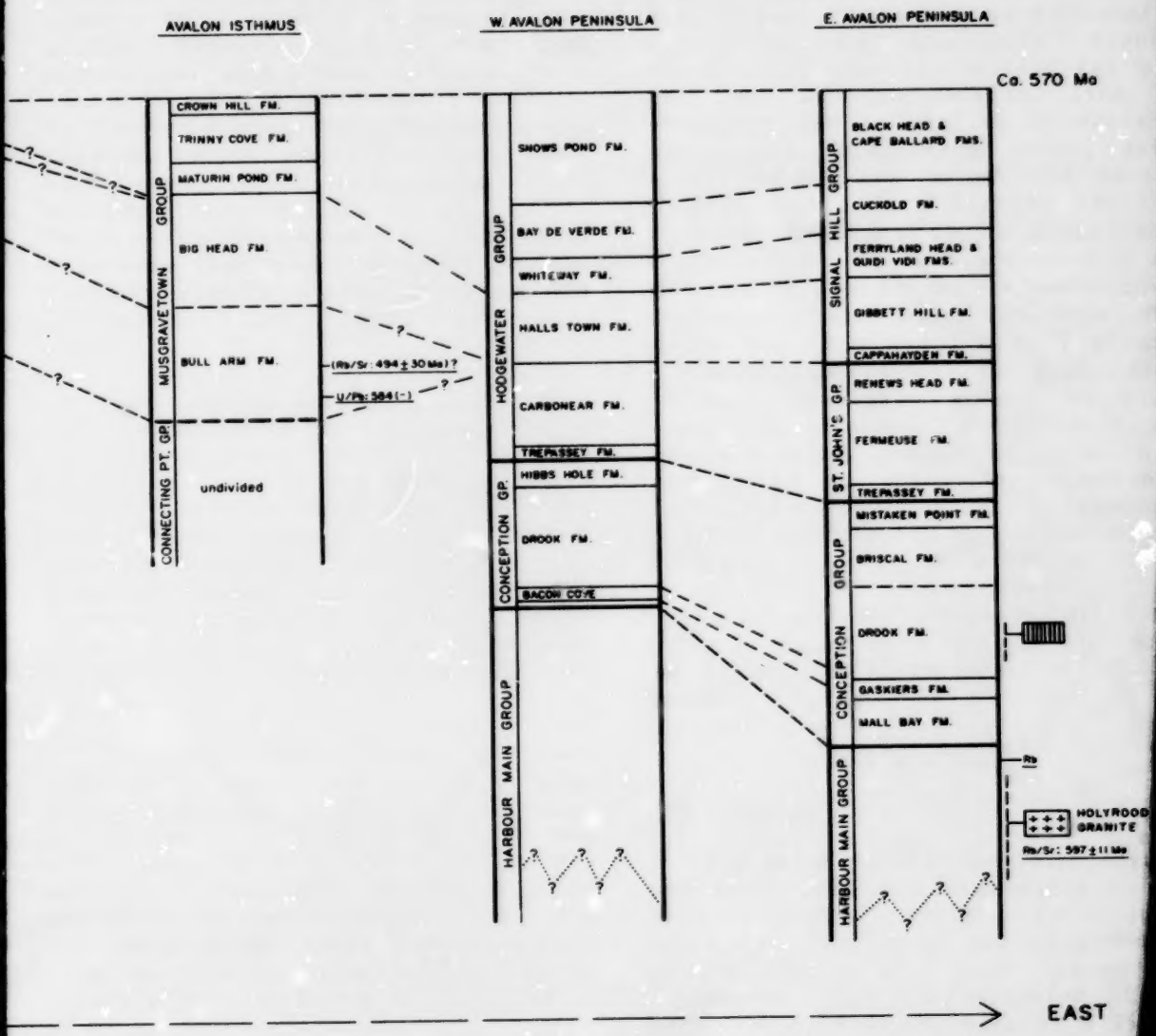


Table 1: Possible stratigraphic correlations across the Avalon Zone in Newfoundland. (Sources as follows: **A**, Williams, 1971; **B**, O'Brien and Nunn, 1980; **C**, O'Brien, 1979; **D**, O'Driscoll and Muggridge, 1979; **E,F**, McCartney, 1967; **G**, Williams and King, 1979).


AVALON ISTHMUS
W. AVALON PENINSULA
E. AVALON PENINSULA
Ca. 570 Ma
CROWN HILL FM.
TRINNY COVE FM.
MATURIN POND FM.
BIG HEAD FM.
BULL ARM FM.
undivided
CONNECTING PT. GP.
MUSGRAVETOWN GROUP
(Rb/Sr: 494 ± 30 Ma)?
U/Pb: 584(-)
SNOWS POND FM.
BAY DE VERDE FM.
WHITEWAY FM.
HALLS TOWN FM.
CARBONEAR FM.
TREPASSEY FM.
HIBBS HOLE FM.
DROOK FM.
BACON COVE
CONCEPTION GP.
HODGEWATER GROUP
HARBOUR MAIN GROUP
BLACK HEAD & CAPE BALLARD FMS.
CUCKOLD FM.
FERRYLAND HEAD & GUDI VIDI FMS.
GIBBETT HILL FM.
CAPPAHAYDEN FM.
SIGNAL HILL GROUP
RENEWS HEAD FM.
FERMEUSE FM.
TREPASSEY FM.
ST. JOHN'S GP.
MISTAKEN POINT FM.
BRISCAL FM.
DROOK FM.
GASKIERS FM.
MALL BAY FM.
CONCEPTION GROUP
HARBOUR MAIN GROUP
Rb
HOLYROOD GRANITE
Rb/Sr: 597 ± 11 Ma
EAST

sediments are not as widely developed, and locally molasse facies sediments directly overlie the Proterozoic volcanic assemblage (Williams, 1971; O'Brien et al., 1977; Strong et al., 1978b; Hussey, 1979). The Late Proterozoic continental sediments are conformably to disconformably overlain by shallow marine Late Proterozoic to Cambrian clastic rocks (Walcott, 1900; Van Ingen, 1914; McCartney, 1967; Williams, 1971; O'Brien et al., 1977). On the Avalon Peninsula, the Lower Paleozoic sediments locally unconformably overlie marine sediments and granitoids (Rose, 1952; McCartney, 1967).

Post-Cambrian sedimentary rocks have been documented at several localities in the Avalon Zone, but are of limited aerial extent. In the western Avalon Zone, Devonian and Carboniferous terrestrial clastics unconformably overlie Proterozoic volcanic rocks, Cambrian sedimentary rocks, and pre-Ordovician granitoids (Williams, 1971). Contacts between Ordovician and older rocks in the eastern Avalon Zone are unexposed.

Paleozoic volcanic rocks are only locally preserved within the Avalon Zone. McCartney (1967) and Fletcher (1972) described thin, Middle Cambrian mafic units from the Trinity and St. Mary's Bay areas, respectively. Devonian and Carboniferous volcanic rocks from the Hermitage and Burin Peninsulas have been described by Smith (1975), O'Brien et al. (1977) and Strong et al. (1979).

Plutonic rocks of the Avalon Zone can be divided into two broad categories on the basis of age of intrusion and degree of deformation. Late Proterozoic intrusions are dominantly foliated to massive, hornblende-biotite granites, granodiorites and syenites with lesser amounts of quartz diorite, diorite and gabbro. Devonian to Carboniferous plutons consist mainly of nonfoliated alaskitic granite, biotite and hornblende-biotite granite with minor diorite and gabbro.

The structural style of the eastern Avalon Zone is characterized by open, doubly plunging folds, and horsts and grabens bounded by vertical faults. The central part of the zone is dominated by vertically to shallowly dipping monoclinal sequences, whereas the part in the western Avalon Zone is characterized by upright to westerly overturned folds with strong axial planar foliations, normal and reverse faults, and a late Acadian regional flexure. Evidence for a Proterozoic orogenic event is best preserved in the weakly deformed and metamorphosed sequences of the Avalon Peninsula. This event has been named the "Avalonian orogeny" (Lilly, 1966). In Newfoundland it is represented mainly by block faulting, granitoid emplacement and gentle folding, and is not known to be accompanied by extensive metamorphism and fabric development. Elsewhere, penetrative deformation and associated greenschist facies metamorphism is now interpreted to be the result of the Devonian Acadian orogeny (Williams, 1971; Strong et al., 1978a,b; O'Driscoll and Strong, 1979; Dallmeyer et al., in press).

GENERAL GEOLOGY

Introduction

The Baine Harbour and Point Enragée map areas are underlain mainly by two extensive Proterozoic stratigraphic units, the Marystown and Musgravetown Groups (Table 2). These groups are juxtaposed along the extension of the Paradise Sound Fault, part of a 250 km long structural feature extending from Bonavista Bay in the north to the southern Burin Peninsula. Marystown Group rocks to the west of this fault represent extensive, dominantly subaerial volcanism and comagmatic plutonism, whereas the Musgravetown Group rocks to the east of the fault are the products of shallow to deep water marine sedimentation and early restricted volcanicity. Shallow marine sediments of Late Proterozoic age

Table 2: Table of formations for the Baine Harbour and Point Enragee map areas.

CAMBRIAN

UNIT 9 (UNDIVIDED CAMBRIAN): red and green shales, pink limestones, red shales with pink limestone nodules.

– – – – – disconformable/faulted contact – – – – –

RANDOM FORMATION (UNIT 8): white orthoquartzites, quartz sandstones; interbedded micaceous siltstones.

disconformable on 2 – – – / – – – conformable on 7e

HADRYNIAN

MUSGRAVETOWN GROUP (UNIT 7)

- **7e:** pebbly sandstones, arkosic sandstones, red monomict breccias, quartzose sandstones.
- **7d:** laminated siltstone and shale; sandstones; gray argillites and conglomerates.
- **7c:** black pyritiferous shales, black flaggy siltstones, sandstone-shale sedimentary breccias.
- **7b:** massive to well bedded, medium to coarse grained sandstones, pebbly sandstones and siltstones; minor conglomerates and laminated argillites.
- **7a:** mafic agglomerates and tuffs; minor mafic flows.

– – – – – – – –(fault contact with 2)– – – – – – – – – –

UNIT 6 (GRANITOID INTRUSIVE SUITE)

Undivided units 6a-6g; hb. ± bi. granodiorites and granites, hb. gabbros, alaskites, monzonites, basaltic and rhyolitic dikes.

–(intrusive contacts with 2,3: not in contact with 4,5)– – –

MARYSTOWN GROUP (UNITS 2 & 5)
U/Pb zircon 608 ± 20 Ma

- **5c:** xenolithic quartz-feldspar porphyry and associated breccias.
- **5b:** mafic volcanic breccias and conglomerates; red volcanogenic sandstones; welded tuffs.
- **5a:** very coarse grained heterolithic volcanic breccias; minor rhyolitic monolithic breccias.

– – – – – – – – – – – – (not in contact)– – – – – – – – – – – –

- **4:** amygdaloidal basalts, mafic tuffs, mafic volcanic breccias; minor red volcaniclastic sandstone.

– – – – – – – (conformable/faulted contacts)– – – – – – –

- **3:** gray and green volcanogenic sandstones and granule to pebble conglomerates; cross-laminated feldspathic litharenites and arenites; minor red conglomerates and red and green arkosic sandstones.

– – – – – – – – – –(conformable contacts)– – – – – – – – –

- **2f:** epiclastic and clastic sediments; may include possible equivalents of Unit 3 clastics.
- **2c:** strongly welded ash flow tuffs and associated tuff breccias.
- **2d:** rhyolite porphyry; includes some unseparated felsic volcanics.
- **2c:** predominantly fine to coarse grained mafic tuffs and associated pyroclastics; minor mafic flows; chlorite schist.
- **2b:** predominantly mafic flows; includes some mafic pyroclastics; minor volcaniclastic lenses; chlorite schist.
- **2a:** predominantly felsic flows and tuffs; minor mafic pyroclastics; minor volcaniclastics; sericite schist.

– – – –(fault contacts with 1 – presumed unconformity)–

PARADISE SOUND FAULT

BURIN GROUP (UNIT 1) U/Pb zircon 700 ± 2 Ma

- **1c:** massive, brecciated and pillowed mafic flows; mafic aquagene tuffs.
- **1b:** massive and bedded mafic tuffs and agglomerates, breccias, cherts and shales.

exposed in several small fault wedges and outliers east of the fault are time stratigraphic equivalents of the Musgravetown Group. Exposures of fossiliferous Lower Cambrian strata are restricted to the area east of the Paradise Sound Fault. Granitoid rocks are intrusive into Marystown Group volcanic and sedimentary rocks; no granitoid rocks were observed east of the Paradise Sound Fault.

The absolute age of the Musgravetown Group in the study area is unknown; it passes conformably upward into fossiliferous Lower Cambrian strata. The contact between the Marystown Group and Late Proterozoic rocks in the present map area is interpreted to be disconformable; similar contact relations are exposed in the southern Burin Peninsula (O'Brien et al., 1977; Strong et al., 1978b). Rhyolite porphyries from the Marystown Group in the Baine Harbour area have been dated isotopically (U/Pb in zircons) at 608 ± 25 Ma (Dallmeyer, 1980) indicating an Upper Hadrynian age for the group.

Evidence bearing on the relative ages of these two groups is lacking, as the contacts between them are everywhere unexposed or faulted. Elsewhere in the western Avalon Zone, within the Musgravetown Group, sedimentary rocks overlie Late Proterozoic volcanic rocks, the Bull Arm Formation (McCartney, 1967; Jenness, 1963). This volcanic sequence is similar in lithology to the Marystown Group and has been isotopically dated at 584 Ma (minimum U/Pb age: Dallmeyer, 1980). If correlation of the Marystown Group and the Bull Arm Formation is correct, then it may be inferred that the bulk of Musgravetown Group sedimentation postdates the Late Proterozoic volcanism of the Marystown Group.

A third, Proterozoic stratigraphic unit, consisting of submarine mafic volcanic and volcaniclastic rocks, is exposed on several small islands in the southernmost part of the Baine Harbour area. Its stratigraphic position, relative to the Marystown Group, is unclear in the field. On the basis of lithological similarities, these rocks are interpreted as correlatives of the circa 760 Ma Burin Group (Strong et al., 1978a,b) exposed south of the present map area. If these correlations are valid, then these rocks must predate the Late Proterozoic volcanism and sedimentation of the Marystown and Musgravetown Groups. In support of this notion, Hiscott (1981) interpreted the contact between the Burin and Musgravetown Groups as an unconformity, with the Burin Group being the older succession.

Unit 1

Definition, distribution and thickness

A sequence of submarine mafic flows and related aquagene tuffs, breccias and sediments outcrops in the southwestern part of the Baine Harbour sheet, underlying the northern part of Davis Island, the southern half of Flat Island, and Yardie, Tinkershire and Glimshire Islands to the east. Contacts with adjacent units are faulted.

A minimum thickness of approximately 500 m of this unit is exposed on Davis Island, but the presence of numerous small faults within the section leaves this estimate open to error.

Lithology

Unit 1 is divisible into two main facies: 1a, a series of massive and brecciated mafic flows, pillow lavas and related pillow breccias with minor amounts of mafic aquagene tuffs, and 1b, bedded and massive mafic tuffs, mafic agglomerate and bedded breccia, olistostromal breccias and lesser amounts of bedded chert, mafic sediment and black shale.

Mafic flows of Unit 1a are best exposed on Glimshire Island and the southeastern side of Flat Island Cove.

They are generally structureless, with only local development of layering parallel to local intercalations of bedded mafic tuff. Zones of monomict mafic breccia occur sporadically in the massive flow units. These are unoxidized and may represent submarine brecciation of a moving flow. The lack of rounded fragments and the absence of intense alteration may be interpreted to preclude an origin through gas brecciation.

On the southeastern tip of Flat Island and the western end of Yardie Island, the mafic flows are pillowed; individual pillow structures range from <30 cm to 1 m in maximum dimension (Plates 1 and 2). Originally prolate to spherical pillow shapes are locally altered by movements along faults and narrow shears. Zones of mafic breccia containing fragmented pillow selvages occur in the pillowed flow units. Associated mafic aquagene tuffs and tuffaceous sediments are well bedded and locally graded.

The pillowed flows are fine grained to slightly porphyritic, locally variolitic, containing clinopyroxene and lesser amounts of olivine phenocrysts in an intergranular matrix of plagioclase, chlorite and magnetite. The main alteration phases are actinolite, clinozoisite, chlorite and hematite. The mafic volcaniclastic rocks are characterized by widespread epidotization, chloritization and actinolitization.

Pyroclastic and clastic rocks of Unit 1b are well exposed on Flat Island and Davis Island. Immature, mafic graywacke and bedded tuffs of this facies outcrop along the south shore of Glimshire Island, along the south side of Flat Island Harbour and on the western headland of Flat Island Back Cove.

Dark gray and black, sedimentary breccias are common on the southeastern part of Flat Island and on the north shore of Davis Island, west of Davis Island Harbour. On Flat Island, breccias are spatially associated with mafic pyroclastics and coarse grained clastic and volcaniclastic sediments. These breccias are poorly sorted, containing subangular to rounded blocks of basalt, limestone, graywacke and mafic pyroclastics (Plate 3). Blocks range in diameter from 1 cm to 1.5 m, with the average grain size between 5 and 20 cm. Limestone occurs as rounded 5 to 10 cm blocks and as disrupted beds and lenses, the largest of which is 1.5 m thick and 6 m long. Smaller blocks are locally fossiliferous, containing fragmented stromatolites (Plate 4).

On the north shore of Davis Island, lithologically similar breccias are spatially associated with siliceous argillite, chert, black slate, conglomerate and minor mafic volcanic breccia. The sequence in this area is disrupted by numerous faults; however, some evidence of primary interdigitation of rock types is preserved. The argillites are black and gray, thinly laminated to massive, and locally display soft sediment deformation features. Thin, discontinuous zones of pebble conglomerate occur as localized intercalations in the finer grained siliceous clastics. The argillites form the matrix of limestone-bearing breccias interbedded with this sequence. Limestone and calcareous sandstone also occur as discontinuous beds or lenses in the breccias. Locally, the breccias are intercalated with poorly sorted cobble conglomerate and black pyritiferous slate. The conglomerate is matrix-supported and contains a variety of subrounded felsic volcanic and sedimentary rock clasts, loosely dispersed in an argillaceous to fine sand matrix.

Sheared, pyritiferous black slate occurs in fault contact with mafic agglomerate, tuffaceous sandstone and conglomerate on the east side of David Island Harbour and as intercalations in limy breccias and conglomerates on the north shore of Davis Island.

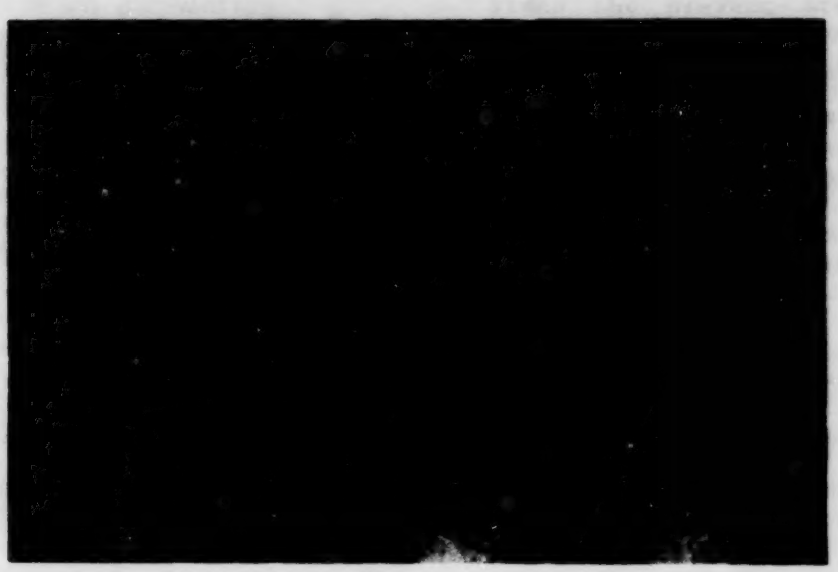


Plate 1: Pillowed and brecciated basalt flows of the Burin Group (Unit 1a). Flat Island, Placentia Bay.

Plate 2: Pillowed basalt lava flow of the Burin Group (Unit 1a). Yardie Island, Placentia Bay.

Plate 3: Sedimentary breccias of the Burin Group (Unit 1b). Flat Island, Placentia Bay.

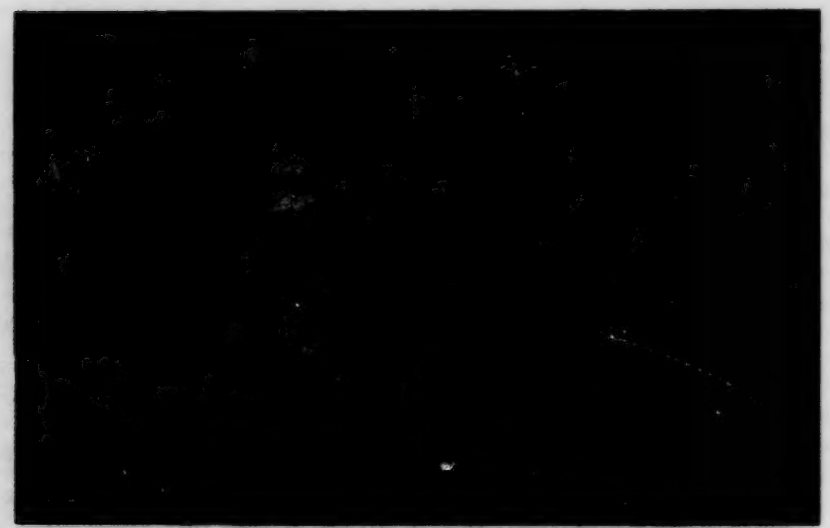


Plate 4: Stromatolite-bearing limestone clast in breccias of the Burin Group (Unit 1b). Flat Island, Placentia Bay.

Contact relations and correlation

Unit 1 is lithologically similar to and lies directly along strike from the Burin Group of Strong et al., 1978a. In its type section in the Southern Burin Peninsula, the Burin Group was originally interpreted to overlie conformably marine sediments, named the Rock Harbour Group (Strong et al., 1978a). On the basis of work in the Flat Islands area, O'Brien and Taylor (1979) suggested that the stratigraphic relationships proposed by Strong et al., 1978a could not be applied to the Burin Group succession exposed there. On the basis of further work on the Flat Islands, Hiscott (1981) suggested that the Burin Group unconformably underlay the Rock Harbour Group. Recent geochronological studies on gabbros of the Burin Group and clasts in the Rock Harbour Group (Krogh, personal communications, 1981) indicate that some 150 Ma intervene between formation of the Burin Group and later deposition of the Rock Harbour Group (Musgravetown Group of this report). These data are in agreement with an unconformable relationship between the Burin Group and the adjacent sediments in the Flat Islands area; the Burin Group is thus interpreted as the oldest stratigraphic unit in the map area.

Nevertheless, problems with these units remain unsolved. On the southwestern tip of Flat Island (approximately 350 m southwest of Roche Peak), a west dipping sequence of coarse grained sandstone underlies massive mafic flows. The sandstones are gray and reddish-brown, very crudely graded and contain discontinuous lenses of granule conglomerate. Near the contact with basalt, the sandstones are red. The sandstones are intruded by mafic sills and dikes up to 45 cm thick, and are in conformable contact with a 50 cm thick convoluted argillite bed which passes up into red, mafic volcanic breccia. The breccia passes conformably into massive basalt.

Given the present stratigraphic interpretation and geochronlogical control, these clastic rocks must represent a narrow clastic zone within the Burin Group. Such zones are common in the southern most exposures of the Burin Group, south of Burin (Strong et al., 1978a). If, however, these rocks can be proven to be part of the Musgravetown Group, then this relationship challenges the interpretation of Hiscott (1981).

It is further suggested that the name "Rock Harbour Group" be replaced by "Musgravetown Group" to designate the sedimentary rocks in the Flat Island area; the name "Rock Harbour Group" should be abandoned (see Introduction to Musgravetown Group).

MARYSTOWN GROUP (UNITS 2,3,4,5)

Introduction

The name Marystown Group was first used by Strong et al., 1975 to designate the subaerial volcanic and associated sedimentary rocks underlying the area west of the Lewin's Cove Fault on the southeastern Burin Peninsula. The group was extended (O'Brien et al., 1977; Strong et al., 1979; O'Brien, 1979) to include the dominantly subaerial, silicic and mafic volcanic rocks which are disconformably overlain by outliers of fossiliferous Cambrian rocks in the southern Burin Peninsula. There, the group is considered to form a continuous succession of Late Proterozoic age, divisible into five formations and one complex. In its type area the Marystown Group records an initial period of widespread silicic to mafic subaerial and locally subaqueous volcanism succeeded by fluviatile and minor marine sedimentation and a later period of volcanicity resulting in the deposition of mafic lavas and massive ash-flow tuffs.

Despite local differences related to facies variations along strike, the

volcanic-sedimentary sequence underlying large parts of the Baine Harbour and Point Enragée map areas, west of the trace of the Paradise Sound Fault, displays an overall similarity in lithology, stratigraphic position and internal stratigraphy to exposures of the Marystown Group in the southwest, and is correlated with it.

Unit 2

Definition, distribution and thickness

Unit 2 is the most widespread unit of the Marystown Group underlying large areas of the Baine Harbour and Point Enragée areas between the Paradise Sound Fault and the outcrop belt of Unit 3. The base of Unit 2 is unexposed; its upper contact with Unit 3 clastics is conformable. The main outcrop belt of Unit 2 is approximately 20 km wide in the Baine Harbour area. Correlatives of this unit can be traced along strike for over 100 km to the northeast in the Terrenceville (O'Brien and Nunn, 1980), Sound Island (O'Driscoll, 1977b) and Harbour Buffett (O'Driscoll, 1978) map areas.

A continuous section through this unit is nowhere exposed in the study area. The lack of facing criteria and the inhomogeneous facies of the pyroclastic deposits, coupled with repetition by faulting and folding, preclude the establishment of stratigraphic subdivisions for this unit that are mappable throughout both map areas, and make reliable estimation of its thickness impossible. Selected stratigraphic sections of Unit 2 are shown in Figure 5.

Lithology

Felsic pyroclastics and flows
(Unit 2a)

Rhyolite flows and a variety of rhyolitic and rhyodacitic pyroclastic rocks are the most diagnostic rock type of Unit 2, and together constitute more than 50% of its total outcrop area. These rock types are well exposed in several areas in the Baine Harbour map area: e.g. between Bay de l'Eau Head and Cape Roger Bay and thence northeastward to Cape Roger Mountain; between the communities of Red Harbour and Boat Harbour West; between Gallows Harbour and Bay de l'Eau; and on many of the numerous small islands in Placentia Bay. Rocks of these compositions form relatively poor exposures in the Point Enragée map area. With the major exception of the Eastern Blue Hills and the Garnish Blue Hills, they characteristically form glacially rounded, lichen-covered outcrops.

Felsic tuffaceous rocks of ash flow and air fall origin are the most common pyroclastic deposits and occur at several structural levels within Unit 2. These are commonly intercalated and tectonically interleaved with coarser grained tuff breccias and agglomerates of similar composition. Along the western shore of Paradise Sound and between Sound Island and Cape Roger and along strike to the northeast, the ash flows are intercalated with mafic flows and pyroclastics and related mafic sills. The ash-flow deposits comprise tuffaceous rocks which range in grain size from ash tuffs through lapillistones, to tuff breccias (Plate 5). The proportion of lithic, crystal and vitric components is highly variable. Likewise, the degree of welding and primary flattening within these deposits is highly variable. The ubiquitous faulting and shearing within the pyroclastic sequences prevents the establishment of regionally mappable cooling units. Although nonwelded, partially welded, and strongly welded zones (locally associated with basal flow breccias) can be recognized in certain exposures, these zonal subdivisions can rarely be extended on a regional scale, and are therefore not shown on the accompanying geological maps.

Nonwelded lapilli tuffs, identifiable in areas of low strain, are

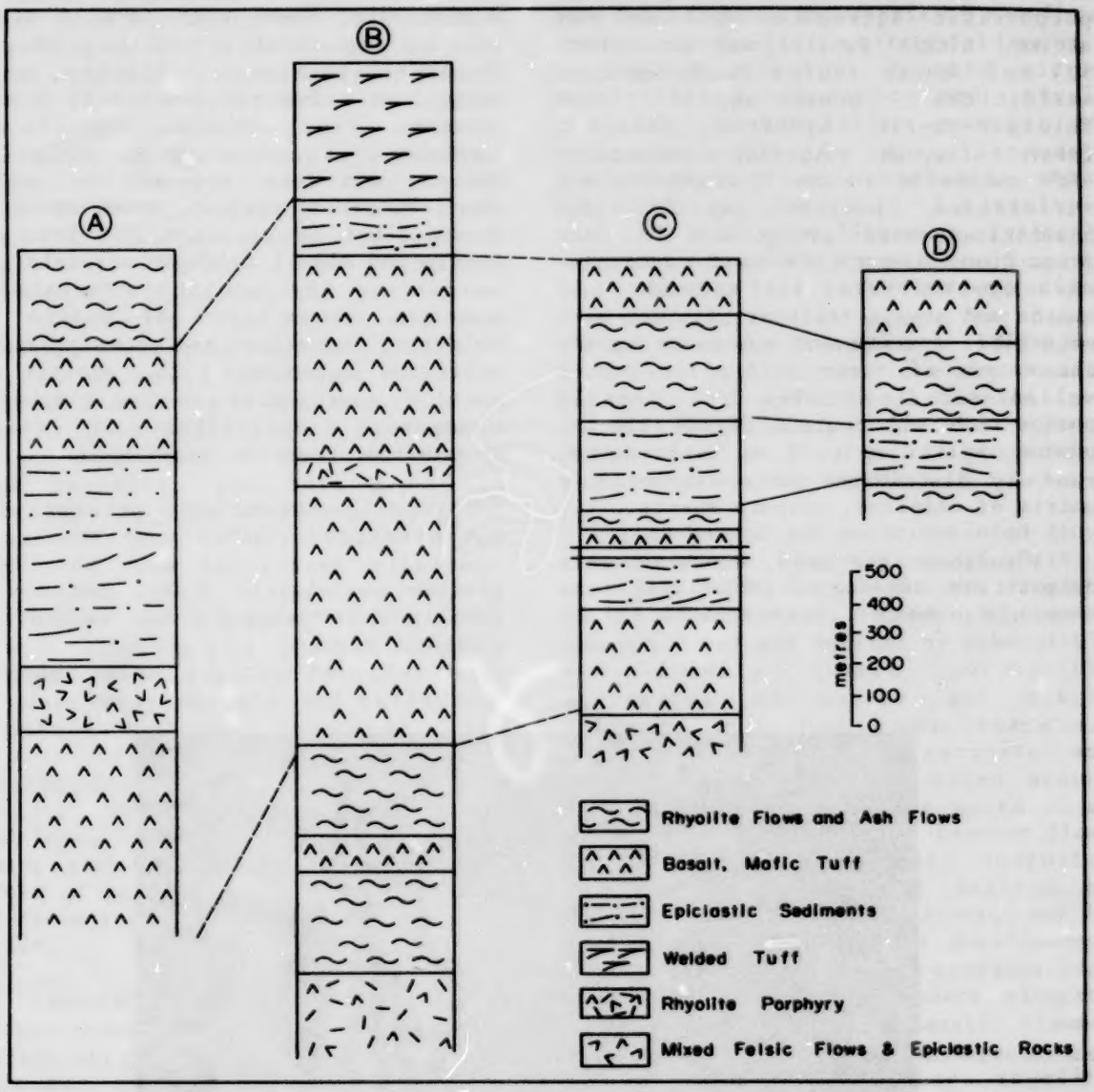


Figure 5: Representative sections through selected parts of Unit 2 of the Marystown Group in the Baine Harbour and Point Enragée areas. A: Central Point Enragée map area; B: Island Pond area; C: Cape Roger Peninsula; D: Petit Forte area.

characterized by subhedral and euhedral quartz (0.1 to 1 mm), rare hematitized alkali feldspar phenocrysts (≤0.1 mm), and broken crystals and glomeroporphyritic aggregates (<2 mm) of albite. Lithic lapilli may constitute 50% of these tuffs and include sericitized quartz-phyric and feldspar-phyric rhyolites, felsite, felsic tuffs, and subordinate magnetite-rich metabasic rocks. Granophyric and sericitized pumice lapilli and hematitized shards are present in minor proportion. A sericite- and carbonate-rich cryptocrystalline aggregate of quartz and alkali feldspar together with magnetite, apatite and muscovite typify the matrix of these tuffs. The poorly welded ash-flow tuffs are locally pumice-rich and contain 25-30% altered pumice lapilli up to 3 mm in diameter, randomly distributed in a vitroclastic matrix of oxidized, cuspate shards.

Throughout the area, rocks of this composition and degree of welding have commonly been metamorphosed to quartz-sericite schists. In hand specimen, the schists are either white or rusty brown, friable, and typified by a penetrative, or locally anastomosing schistosity. These rocks are in places cut by sigmoidal aggregates of pink feldspar, quartz and chlorite, which vary from a few centimetres to 1 m in length. Fine, platy crystals of sericite, together with chlorite, opaques and very rare biotite, define the pervasive foliation, which abuts and forms augen of strained and fractured quartz and alkali feldspar crystals. The matrix of the schists consists of subequal proportions of quartz and feldspar, hematite and submicroscopic micaceous aggregates. The schists are locally quartz-free and plagiophyric, suggesting protoliths of either rhyodacite or dacite composition.

Volcanic breccias, primarily of pyroclastic origin, are generally spatially associated with the finer grained pyroclastic flows, but may be locally intercalated with chloritized

Plate 5: Welded lithic tuffs of the Marystown Group (Unit 2a). Near Gallows Harbour, Placentia Bay.

metabasic flows and mafic tuffaceous sediment. The breccias are monolithic and heterolithic, but contain fragments of felsic composition only. Grain size varies from coarse grained tuff breccia containing 6 to 8 cm blocks, to very coarse agglomerate with isolated blocks greater than 1 m in diameter. At Jigging Cove in the Baine Harbour map area, coarse agglomerate displays plastic deformation features which affect bombs up to 50 cm in length. Bombs of rhyolite, red vitrophyre and welded tuff are rimmed by a chilled cryptocrystalline aggregate, suggesting the cooling of hot, pyroclastic deposits. At the same locality, finer grained, monolithic tuff breccia contains 10-20 cm rhyolite fragments which have been contorted by syn- or post-depositional flowage, a feature diagnostic of basal pyroclastic flow deposits. The matrix of the breccias is partly recrystallized, but relict vitroclastic textures are preserved.

In the central parts of the Point Enragée area, coarse grained volcanic breccias also outcrop together with volcanic conglomerate and tuffaceous sandstone. These breccias are heterolithic, unsorted and contain rounded fragments (1 cm - 1 m) of rhyolite, welded tuff, basalt and red sandstone. The matrix of the breccias is sandy, rich in detrital feldspar, and devoid of primary pyroclastic textures. The above features suggest an epiclastic origin.

Rhyolite flows constitute less than 10 per cent of Unit 2 and outcrop sporadically throughout both map areas. With the exception of the rhyolite porphyry in the southwestern Baine Harbour sheet, the flows do not form mappable lithologic units. Four types of rhyolite have been recognized; they include massive, flow-banded, spherulitic and autobrecciated flows. The massive flows are best exposed west of the Bay de l'Eau River, near Landwash Pond. They are typically pink or buff colored, porphyritic and aphyric, and may be either glassy or saccharoidal in texture. Embayed subhedral quartz phenocrysts (0.1 - 10 mm) form the main phenocryst phase; albite euhedra and rarely preserved microcline phenocrysts are subordinate. The matrix of the flows is a sericitic quartzofeldspathic aggregate which is locally microspherulitic, felsitic and rarely perlitic. Spherulitic growths are ubiquitous in the more intensely devitrified flows, especially those adjacent to the Unit 6 granitoid massifs. The spherulites are typically composed of radial aggregates of quartz and alkali feldspar with spherical outlines; individual spherulites rarely exceed 5 mm in diameter. An individual thin section of these flows may consist of up to 70% spherulites disposed in a cryptocrystalline, quartz microporphyritic, or finely comminuted quartzofeldspathic matrix.

Flow banded and autobrecciated flows constitute a minor part of Unit 2 rhyolites. The flow bands are straight to highly contorted. Macroscopic flowage bands (<1 cm) are defined by spherulitic and locally quartz porphyritic aggregates of quartz and alkali feldspar. Individual bands, characteristically altered to sericite and epidote, abut and form augen around embayed quartz phenocrysts up to 10 mm in grain size. The finely layered flows are marked by delicately contorted flowage bands (<.1 mm) defined by hematite and acicular opaques, and by widespread microspherulite development. The matrix of these flows contains iron oxide dust and locally bears elongate (<25 mm) zones rich in eutaxitic fiamme. The flows are locally autobrecciated and consist of angular rhyolite fragments (<1 mm to 10 cm) in maximum dimension in a finely comminuted, pervasively altered matrix characterized by sericite, epidote and carbonate aggregates.

Mafic volcanic rocks (Units 2b and 2c)

Flows and pyroclastics of mafic composition are not as areally extensive

as their felsic equivalents, and underlie approximately 100 km^2 within the outcrop area of Unit 2. The mafic volcanic rocks include aphyric and vesicular basalt flows, mafic tuff and agglomerate, plagiophyric tuff, and thermally metamorphosed equivalents. They are exposed in three main belts, in both map areas. The easternmost belt is well exposed on the Baine Harbour sheet, between Paradise Sound and Cape Roger Bay, in particular along the shorelines of Petit Forte Harbour and Nonsuch Inlet and thence north and northeast to the northern boundary of the map area. In this area mafic flows, sills and equivalent chlorite schist are interbedded and, more characteristically, tectonically interleaved with Unit 2 felsic pyroclastics. Massive mafic flows occupy the core of an open syncline near Nonsuch Head. Along strike to the northeast, similar flows overlie ash-flow tuff in several tighter synclinal structures.

Aphyric and finely vesicular mafic volcanic rocks outcrop in a fault-bounded, irregularly shaped zone between Rushoon River and Powderhorn Lake in the west-central part of the Baine Harbour area. There, mafic flows predominate, mafic tuff is subordinate, and intercalated felsic volcanic rocks are rare. A smaller synclinal structure, between Broad Cove Head and Red Harbour, contains roughly equal proportions of interstratified basalt flows, fine and coarse grained mafic pyroclastics, and immature, red and brown volcaniclastic sediments.

The third main area of mafic volcanic outcrops occurs in the east-central part of the Point Enragée area, between Bluff Head in the west and the Late Proterozoic-Cambrian outlier at Island Pond in the east. The northern extension of this openly folded belt is truncated by Unit 6 granitoid massifs, adjacent to which the mafic rocks have undergone widespread thermal metamorphism. Aphyric basalts, fine grained mafic tuff and mafic hornfels are the characteristic mafic rock types in the northern part of this area. Near Horn Hill Pond and Brown Lookout, aphanitic mafic flows and sills are interbedded with volcaniclastic and arenaceous fine to coarse grained clastics which locally constitute up to 30% of the unit. Isolated outcrops of massive felsic volcanic rocks in this area may represent either a primary interdigitation or tectonic intercalation.

The mafic flows *(Unit 2b)* are characteristically massive, rarely amygaloidal, fine grained, plagioclase porphyritic and microporphyritic, and locally aphyric. They are mafic in composition; plagioclase is albitic and occurs as groundmass, microphenocryst and phenocryst phases. Albite phenocrysts (2-3 mm) are zoned and commonly sericitized and epidotized. Euhedral and subhedral laths of albite (0.01 to 0.1 mm) form intergranular textures with actinolitized pyroxene, magnetite and altered mafic glass in the matrix of the flows; fluidized and trachytic textures have been recognized in several samples of this unit. Pyroxene, locally constituting 10 per cent of the flows, is characterized by ubiquitous tremolite-actinolite alteration. The pyroxene is monoclinic; the only identifiable phases are augitic. Olivine is rare and is represented mainly by chlorite and serpentine matrix aggregates. Iddingsitized olivine microphenocrysts were identified in the vesicular flows on Oderin and adjacent islands in the Baine Harbour area.

Aside from Oderin and adjacent islands, the occurrence of coarsely vesicular mafic flows within this unit is uncommon, well exposed mainly in the easternmost mafic volcanic belt. On Oderin Island, thick amydaloidal flows are interbedded locally with red and yellow tuffaceous sediments (Plate 6). The amygdaloidal flows are marked by 1 mm to 1 cm amygdales containing chlorite, quartz, carbonate and, very rarely, prehnite. Other metamorphic

Plate 6: Interbedded basalt and epiclastic sediment of the Marystown Group (Unit 2b). Patrick Island, Placentia Bay.

minerals common in the groundmass include albite, epidote, hematite and magnetite. The flows are characteristically fine to medium grained, albite-phyric and contain altered clinopyroxene and rare iddingsitized olivine as both phenocryst and matrix phases.

Mafic pyroclastic rocks *(Unit 2c)* vary greatly in grain size and include lapilli tuff, tuff breccia and rarely, agglomerate. The mafic pyroclastics are generally poorly sorted and are only locally well bedded (Plate 7). They are typically less extensive than the massive flows but are present throughout all the mafic volcanic outcrop areas. Typical fine grained lapilli tuffs form chloritized, and epidotized, knobby weathering, generally massive and otherwise nondescript outcrops. They are notably rich in either crystals or crystal aggregates of epidote, or chloritized mafic lapilli, and rarely lack a penetrative chloritic foliation. The finer grained mafic tuffs are petrographically typified by 0.1 mm to 6 mm rounded fragments of aphyric or plagiophyric metabasalt and oxidized mafic scoria, locally constituting 60-70% of a single specimen. Epidote-chlorite-magnetite-carbonate aggregates are ubiquitous in the matrix. Plagioclase, partially or totally replaced by epidote, forms subhedral to anhedral crystals and glomeroporphyritic aggregates, which may constitute up to 40% of the crystal-lithic lapillistones. The matrix of the coarser tuff breccias and agglomerate displays a similar pervasive alteration. The breccias contain blocks and bombs (<50 cm) of massive and tuffaceous mafic rocks which are petrographically similar to the flows and pyroclastics described above.

Throughout much of the area, the mafic tuffaceous rocks and, more rarely, mafic flows, were metamorphosed to chlorite schist. This lithology is most common in the Baine Harbour area, but it also forms scattered outcrops in the adjacent Point Enragée area. Chlorite is

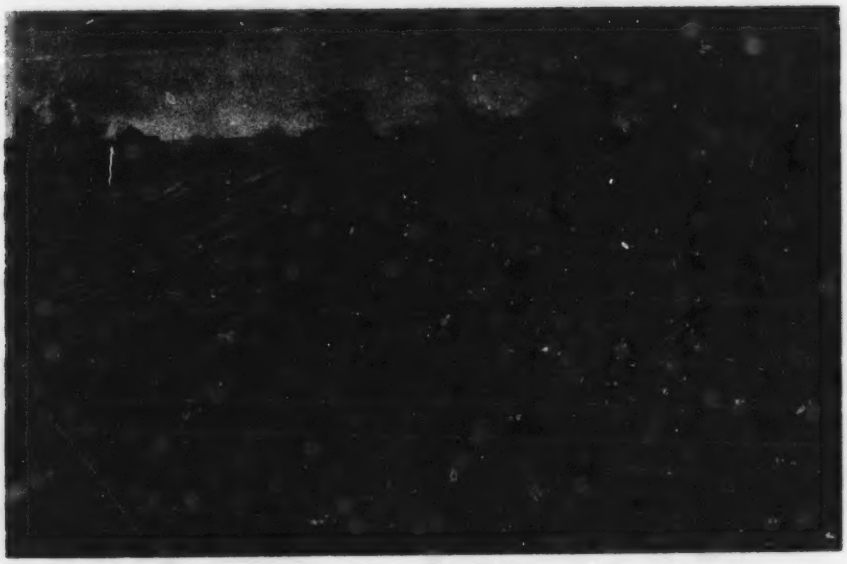


Plate 7: Bedded mafic tuffs of the Marystown Group (Unit 2c). Near Horn Hill, Pt. Enragée sheet.

the main metamorphic phase and defines the penetrative foliation. The metamorphic assemblage of these rocks, as well as the mafic hornfelses, is described elsewhere in this report (see Structural and Metamorphic History).

Rhyolite porphyry (Unit 2d)

Quartz porphyritic rhyolite flows and massive rhyolite porphyries outcrop in a 1-1.5 km wide, 16 km long belt that extends continuously from the southeastern part of the Point Enragée area, northeastward to Baine Harbour. For much of its length, the rhyolite porphyry parallels the strike of adjacent tuffaceous rocks and forms a concordant body within Unit 2. In detail, the rhyolite is interbedded with dominantly felsic volcanic units and rare mafic horizons. Elsewhere fine grained felsic pyroclastics occur as irregular shaped pods up to 1 km^2, which display gradational contacts with the main porphyry body. The porphyry contains from 20-30% euhedral, locally embayed quartz phenocrysts with hematitized alkali feldspar (<20%) and plagioclase in subordinate amounts. Texturally, the matrix varies from cryptocrystalline, felsitic to vitroclastic and rarely equigranular with no apparent systematic variation. Dark, subangular to angular mafic fragments up to 2 cm in length are common throughout much of the porphyry. Where the porphyry is banded, flowage bands both abut and form augen of the xenoliths.

Welded ash flows (Unit 2e)

Densely welded ash-flow tuff occurs as scattered outcrops throughout both map areas, and form an extensive, mappable unit in the central part of the study area, where they underlie the resistant ridges of the Eastern Blue Hills (Unit 2e). At this locality, the ash flows overlie an extensive sequence of aphanitic metabasic flows and fine grained mafic tuff, and are in turn disconformably overlain by Late Proterozoic strata of Unit 7.

The welded tuff is dark brown or red, feldspar- and quartz-phyric, and characteristically displays little or no macroscopic evidence of flattening. The tuff contains strongly stretched pumice lapilli and shards, the latter enclosing albite anhedra; maximum length-width ratios approach 30:1. The eutaxitic pumice is characteristically serrated and may show complete granophyric replacement. An oxidized, cryptocrystalline matrix is common and is locally microspherulitic.

The densely welded tuff is spatially associated with vitric tuff or vitrophyre which, in outcrop, is deep red, aphyric and shows conchoidal fracturing. It contains over 70-80 per cent hematitized, forked and eutaxitic fiamme, in an otherwise cryptocrystalline, locally devitrified matrix. The tuff may contain fine grained (<0.01 mm) ferromagnesian and opaque oxide phases which constitute less than 1% of the rock.

Volcaniclastic and associated sediments (Unit 2f)

Fine to coarse grained, immature clastic rocks occur at several structural levels within Unit 2. These clastics represent epiclastic (cf. Fisher, 1966) volcanic deposits and include bedded volcanic ash, reworked lithic tuff, massive to crudely bedded litharenite and volcanic conglomerate. They vary in extent from outcrop-scale pods and lenses to intraformational units traceable along strike for several kilometres. The largest mappable unit, outcropping in the west-central parts of the Point Enragée sheet, contains a substantial proportion of red, fluviatile conglomerate.

Clastic rocks in the eastern half of Unit 2 are usually confined to several thin beds intercalated with mafic and felsic volcanic rocks. However, larger mappable units interbedded with mafic flows and tuff occur near Nonsuch Arm and east of Cape Roger Bay. There, gray and purple sandstone, granule conglomerate and water-lain lithic and vitric tuff are present (Plate 8). In the north-central parts of the Baine Harbour area, several larger clastic units occur as lenses and synclinal keels in the stratigraphically highest parts of Unit 2. These are dominated by gray and green feldspathic arenites and cobble to pebble conglomerates, and pass upward into the Unit 3 clastic sequence. Several units of clastic sediments and fine to locally coarse grained epiclastic rocks outcrop in the central part of the Point Enragée area, and are well exposed between the Garnish Blue

Plate 8: Graded volcaniclastic sediment of the Marystown Group (Unit 2f).

Hills and Horn Hill Pond. In this area, feldspathic arenites and gray cobble conglomerate predominate. Near Horn Hill the sediments are well sorted and commonly cross-laminated. Near Brown Lookout, the westernmost outcrops of the clastics interdigitate with coarse laharic breccias and associated reworked volcanic deposits.

The volcaniclastic sandstones of Unit 2 are typified by detrital plagioclase and quartz, which constitute up to 60% of the better sorted beds, and a variety of felsic and mafic volcanic detritus. With few exceptions the sandstones are poorly sorted, submature and contain crystal and lithic fragments from <0.01 mm to 2 mm in size. Most of the sandstones are arenaceous in composition. The matrix of the clastic rocks is rich in muscovite, carbonate and chlorite; magnetite is an important accessory, locally forming 5% of the detrital assemblage. The lithic content of the detrital assemblage is rarely less than 30%; volcanic detritus includes welded and unwelded felsic tuff, rhyolite, felsite and rarely granodioritic to granitic intrusives. Where the clastics are within mafic flow units, the latter serve as an important provenance, and the sediments are rich in plagioclase and mafic volcanic rock fragments.

The red clastic succession which outcrops immediately west of the Garnish Blue Hills is dominated by sandstone and cobble-boulder conglomerate. The sandstones contain up to 20% crystals and crystal fragments of strained and embayed quartz, 20-30% albite and hematitized alkali feldspar and >30% volcanic detritus in a calcite- and sericite-rich matrix. Volcanic rock fragments include banded and massive rhyolite, porphyritic rhyolite tuff, and subordinate metabasic tuffaceous rocks. The detrital assemblage of the coarser clastics is essentially similar, being rich in rhyolitic volcanic detritus.

Contact relations and correlation

The contact of Unit 2 volcanic rocks of the Marystown Group with basalt flows of Unit 1 (Burin Group) at Flat Islands is interpreted as a fault, although the contact there is obscured by Quaternary glaciomarine deposits. Elsewhere in the map area, the base of the unit cannot be defined. Unit 2 is gradationally and conformably overlain by terrigenous clastics of Unit 3 in the northwestern part of the Baine Harbour map sheet. In other parts of the map area this contact is either sharply concordant, obscured by granitoid intrusions, or faulted.

On the basis of marked similarities in lithology and stratigraphic position, Unit 2 may be correlated with other major subaerial volcanic formations which form the base of the Late Proterozoic stratigraphic succession in several parts of the western Avalon Zone. These include the Taylor's Bay Formation of the Marystown Group (O'Brien, 1979), the White Point Formation of the Love Cove Group (Hussey, 1979), the Belle Bay (Williams, 1971) and Tickle Point (O'Driscoll, 1977a) Formations of the Long Harbour and Connaigre Bay Groups respectively, and the Deer Park Pond and Southern Hills Formations in the adjacent Terrenceville area (Bradley, 1962; O'Brien and Nunn, 1980).

Unit 3

Definition, distribution and thickness

Unit 3, a succession of fine to medium grained terrigenous clastics within the Marystown Group, overlies and is locally interbedded with felsic volcanic rocks of Unit 2 in the northern parts of the Baine Harbour and Point Enragée map areas. It outcrops in an irregular shaped belt, which is approximately 12 km long and 3 to 4 km wide in the Point Enragée area. The northeastern extension of this unit north of the Grand John Fault reaches a maximum width of 5 to 6 km. The

easternmost clastic rocks in the northeastern part of the belt are interbedded with and gradationally overlie Unit 2 volcanic rocks. In contrast, clastics in the southern part of the belt either directly overlie Unit 2 or are in fault contact with it; no interdigitation is recognized. Thin tuffaceous beds in the southern part of the unit are the only evidence of contemporaneous volcanism.

Because of tight folding and faulting, thickness estimates of this unit in the Baine Harbour area are subject to error. A maximum composite thickness estimate for the sediments of this unit south of the Grand John Fault is in the order of 1.5 to 2 km; this thickness is approximately doubled by the intrusion of Unit 6 diabase dikes and sills (Figure 6).

Lithology

The major rock types in the northern part of this belt include gray and green volcanogenic sandstones and interbedded granule to pebble conglomerates in the lower parts of the succession. Lesser amounts of gray siltstone and thinly bedded gray and green sandstones are interbedded with epiclastic rocks in stratigraphically higher levels of this part of the sequence, northeast of Jacques Fontaine Gull Pond.

The finer grained clastics are mainly light to dark gray and green, medium to coarse grained, feldspathic litharenites. They are moderately or poorly bedded, rarely graded and locally crossbedded. Individual beds average 40 to 50 cm in thickness. Although graded beds are uncommon, heavy mineral bands are present in some of the sandier units indicating a winnowing effect. Scattered paleocurrent data from cross-laminations suggest transport from the north and northeast. The immature feldspathic litharenites in the lowest parts of the sequence are interbedded with nonwelded, crystal-rich, tuffaceous deposits and are interpreted to represent reworked, intraformational epiclastic volcanic deposits. The detrital assemblage is dominated by plagioclase, quartz, opaques and felsic volcanic lithic fragments in a sericitized and locally carbonate-rich, fine grained quartzofeldspathic matrix. Identifiable lithic fragments include (in decreasing amounts): feldspathic rhyolite and rhyolite porphyry, welded ash-flow tuff, unwelded tuff, plagiophyric metabasic rock and unfoliated granitoid. Magnetite is a characteristic detrital mineral; it comprises less than 5% of the immature epiclastics to more than 20% of the well sorted sandstone beds.

Conglomerates form thin, continuous beds and irregular lenses within the litharenites. Matrix-supported conglomerates also occur in the foresets of coarser, crossbedded sandy units. Clast composition is generally similar to the finer grained clastics; one minor variation is the proportion of granitoid detritus in the conglomerates. Pebbles and cobbles of hornblende granite and quartz diorite are common in the higher stratigraphic levels of Unit 3 in the Baine Harbour area, where they comprise up to 10% of the detritus. In contrast, granitoid cobbles are rare in the epiclastic conglomerates interbedded with Unit 2 volcanic rocks. No previously deformed detritus was recognized in any of the clastics of this unit.

Cross-laminated lithic sandstones predominate in that part of the succession exposed between Barasway de Plate and Grand Jersey Cove. The sandstones may be classified as feldspathic arenite and litharenite; proportions of feldspar and felsic clasts vary with no apparent regularity. The sandstone is characteristically cross-laminated (Plate 9); planar bedding is notably rare. Thin sandy laminae commonly form the foresets of the crossbeds. These are typically dark gray but locally have a slight purple hue. In places, the sandy laminae are

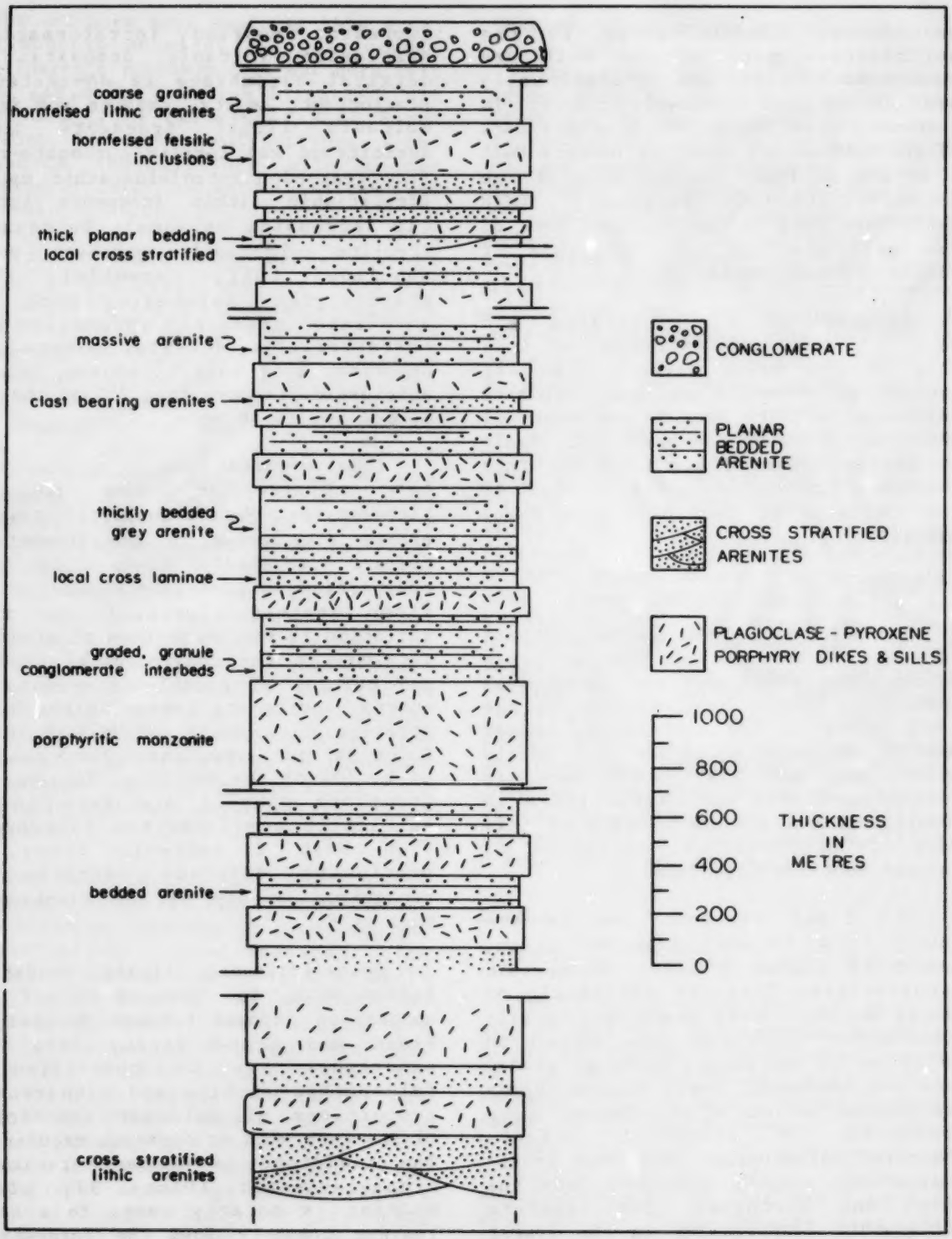


Figure 6: Composite stratigraphic section through Unit 3 of the Marystown Group exposed between Grand John and Point Enragée, 1M/6.

Plate 9: Cross-stratified feldspathic sandstones from Unit 3 of the Marystown Group near Grand Jersey Cove, Fortune Bay.

magnetite-rich. Granules and pebbles of felsic volcanic lithology may be present in the foresets (Plate 10). Individual clasts have a maximum diameter of 10 cm and locally constitute up to 5% of the detrital assemblage. Rocks of similar facies, exposed near Miller Head, contain several thin intercalations of red and green lithic lapilli tuff and tuff breccia. In the highest stratigraphic levels of this facies, exposed in a narrow synclinal core west of Miller Head, the sandstone is dark gray and massive to thickly planar bedded with rare parallel laminated, finer grained sandy interbeds.

The above cross-laminated facies is succeeded to the southwest by relatively well bedded arenites exposed between Peltry Barasway and Wood Cove. In this area, the continuous succession is more than 700 m thick and is dominated by medium to coarse grained quartzo-feldspathic arenite that is characteristically metamorphosed by adjacent metabasic sills of Unit 4. The succession is thickly albeit indistinctly bedded, and rarely graded and cross-laminated. Graded sandstone beds 2 to 5 cm thick constitute less than 5% of the exposed section. The sandstones contain isolated, matrix-supported felsic clasts (1-5 cm) which locally comprise up to 10% of a single outcrop.

A 200 m exposure gap separates the above facies from red terrigenous clastics, interpreted to occupy the highest stratigraphic levels of Unit 3.

Fine to coarse grained, red conglomerates which form the top of the unit in this area are well exposed along the coast between Point Enragée and Wood Cove. This part of the succession is characterized by red and maroon, granule, pebble and rarely, cobble conglomerate with subordinate coarse grained arkosic sandstone. These clastics are locally cross-laminated and graded, and fine upwards through the top several metres of the section. In the uppermost stratigraphic levels, the

Plate 10: Pebbles in foresets of cross-stratified sandstone of Unit 3, Marystown Group.

sandstones are regularly intercalated with thin mafic tuff bands.

Reddish-brown arkosic sandstone, which is in fault contact with the cross-laminated sandy facies of Unit 3 at Grand John Point, may be equivalent to this sequence. There, the sandstone passes conformably upward into massive basalt and coarse grained mafic breccia.

Contact relations and correlation

The terrigenous clastics of Unit 3 north of the Grand John Fault conformably overlie Unit 2 volcanic rocks. The contact is gradational over approximately 30 m; the base of Unit 3 is drawn where clastic beds predominate over tuffaceous beds. In the Point Enragée area this contact is sharp, with clastic sediments directly overlying tuffaceous deposits of Unit 2. Elsewhere, the base of Unit 3 is either fault-modified or truncated by pretectonic granitoid intrusions. The western contact of Units 2 and 3 is unexposed in the Point Enragée area; the extension of this contact east of Deep Bight is faulted.

Exposures of Unit 3 in the present study area mark the southwesternmost extension of a 100 km long, northeast striking belt of volcaniclastic and clastic sediments which extends from Point Enragée to Swift Current. Unpublished maps of Radex Ltd. show that the belt extends through the Tuq Pond map area into the Clode Sound region where it has been identified by Hussey (1979). From there it can be traced northward into the Deer Harbour Formation of the Musgravetown Group (Jenness, 1963; Dalbello, 1977). In the southern parts of the Terrenceville area (O'Brien et al., 1980) and the northern parts of the present map area, this belt is successively offset along a series of east-west and northwest trending right-lateral faults. The belt does not extend south of Point Enragée.

Unit 3 shows marked similarities to both the northeastern extension of the belt (Unit 1d of O'Brien and Nunn, 1980) and to some of the clastic deposits of the Anderson's Cove Formation in the adjacent Terrenceville area (O'Brien and Nunn, 1980); both are considered time-stratigraphic equivalent. The upper parts of Unit 3 exposed south of the Grand John Fault are similar to parts of the Anderson's Cove Formation in that they are more mature, well bedded and finer grained than the exposures north of the fault. Like the Anderson's Cove Formation in the Terrenceville area, this succession is marked by the reddening of its uppermost clastics.

Unit 3 also represents time-stratigraphic equivalents of the Musgravetown Group in the Bonavista Bay region, in particular, the Deer Harbour Formation of Jenness (1963).

Unit 4

Definition, distribution and thickness

Unit 4 consists of a succession of massive mafic volcanic rocks, containing few pyroclastic intercalations, which conformably and gradationally overlies coarse red conglomerates assigned to the uppermost levels of Unit 3. It is best exposed in and adjacent to the village of Point Enragée. There, a maximum thickness of approximately 750 to 1000 m of porphyritic and amygdaloidal basalt and breccia is exposed.

Lithology

Exposures of Unit 4 typically consist of vesicular and amygdaloidal basalt flows of variable thickness, that contain 1 mm to 5 cm amygdales filled with calcite, prehnite, quartz and chlorite. Aside from their characteristic vesicularity, flows display few other internal features. Rare intercalated red clastic lenses, most common at the basal parts of the unit, indicate that subaerial conditions continued to predominate during this episode of volcanicity. Mafic tuffaceous rocks, occurring as intercalated lenses and beds up to 5 m thick, outcrop at several stratigraphic levels within the sequence at Point Enragée. They are crudely graded and locally cross-stratified, possibly indicating some reworking in subaqueous conditions.

Monolithic breccia comprises a relatively minor proportion of this unit and is exposed immediately south and southeast of Point Enragée. In places the breccia contains 5 to 15 cm long angular fragments of aphanitic or vesicular basalt in a matrix consisting of subequal proportions of angular mafic lapilli and scoriae and epidotized mafic ash. Elsewhere the breccia contains relatively well rounded, coarsely amygdaloidal basalt lapilli and blocks (locally up to 1 m in diameter) within a matrix of red sand and palagonite. The mafic blocks locally display concentric, epidotized and silicified rims. In the first case, the breccia may represent blocky lava flows, whereas the latter type is more consistent with laharic deposition, possibly reworking both massive flows and agglomerate.

The bulk of the vesicular and amygdaloidal flows in and around Point Enragée are basaltic in composition. They are fine to locally medium grained, porphyritic and rarely microporphyritic, and are characterized by phenocrysts of albite and clinopyroxene. Iddingsitized olivine occurs as rare 2-3 mm phenocrysts, more commonly as microphenocrysts and also as a matrix phase locally forming ophitic to subophitic textures with albite. Groundmass textures are typically intergranular and less commonly intersertal or holocrystalline. Groundmass phases also include chlorite, epidote, actinolite (after pyroxene), sphene, leucoxene and rare apatite; hematite and undifferentiated opaques are ubiquitous in the matrix. Amygdales range in diameter from <1 mm to >2 cm and in shape from spherical to amoeboid; they locally constitute more than 30% of the rock. Chlorite and calcite are the

dominant phases in the amygdales; lesser proportions occur of quartz, prehnite, zoisite and, rarely, pumpellyite.

As with most mafic pyroclastic rocks in the map area, the mafic tuff of Unit 4 is pervasively chloritized and epidotized. Plagiophyric and vesicular basalt which occurs as lithic lapilli and larger blocks is petrographically similar to the massive flows of this unit.

Contact relations and correlation

The mafic rocks of Unit 4 gradationally and conformably overlie red conglomerate at the top of Unit 3; the contact is drawn at the first occurrence of mafic tuff in the clastic succession. The tuffaceous rocks are thinly and regularly interbedded with coarse to fine grained red sandstone over a thickness of a few metres. The tuffaceous beds are succeeded upward by massive, thick amygdaloidal basalt flows. Several metres below the contact, red sandstone is cut by plagioclase-pyroxene porphyritic metabasic sills which may be related to the overlying mafic volcanic rocks.

Unit 4 is lithologically similar to mafic volcanic formations which overlie fluviatile to marine clastic rocks elsewhere in the Fortune Bay area; these are the Mooring Cove Formation of the Long Harbour Group (Williams, 1971) and the Doughball Point Formation of the Connaigre Bay Group (O'Driscoll, 1977a). Mixed mafic and dominantly felsic pyroclastic volcanic sequences occurring at a similar stratigraphic position elsewhere on the Burin Peninsula may be time-equivalent to Unit 4. These include the Calmer Formation (O'Brien, 1979) and its equivalents on the southern and central Burin Peninsula (i.e. Mortier Bay Formation, Taylor, 1976), and the extensive unnamed volcanic deposits northeast of the Ackley Granite in the Sound Island map area (Hussey, 1979). Unit 4 is also correlated with the Southwest River Formation (Hussey, 1979) of the Love Cove Group in the Bonavista Bay area.

Unit 5

Definition, distribution and thickness

Unit 5 is a sequence of subaerial, epiclastic and pyroclastic flows and synvolcanic porphyry which outcrops between Doughball Cove and Bluff Head, on the western coast of the Burin Peninsula. The stratigraphic position of this unit is uncertain, as its contacts with other volcanic rocks of the Marystown Group are unexposed. Several hundreds of metres of tuff and breccia epiclastic outcrop in the southern part of the unit (Figure 7), but the lack of primary orientations elsewhere prevents any reliable estimate of total thickness for the unit. Although rocks of Unit 5 are discussed here with the Marystown Group, evidence for such correlation is equivocal. Alternative stratigraphic correlations with Paleozoic volcanic rocks are discussed below.

Lithology

Xenolithic quartz-feldspar porphyry (Unit 5a)

The part of Unit 5 which outcrops north of Seal Cove consists of several rock types, the most extensive of which is a dominantly xenolithic quartz-feldspar porphyry. The porphyry is spatially related to breccias of pyroclastic, epiclastic and intrusive origin. Only the intrusive breccias are interpreted as having a clearly genetic link with the porphyry.

The porphyry *(Unit 5a)* varies in color from brown, maroon, or gray to yellow, and is characteristically fine to fine/medium grained. Quartz and alkali-feldspar phenocrysts vary in proportion, with quartz always predominant. Although the proportion of xenoliths varies widely, the porphyry is rarely xenolith-free. Cognate xenoliths include felsite and fine grained quartz

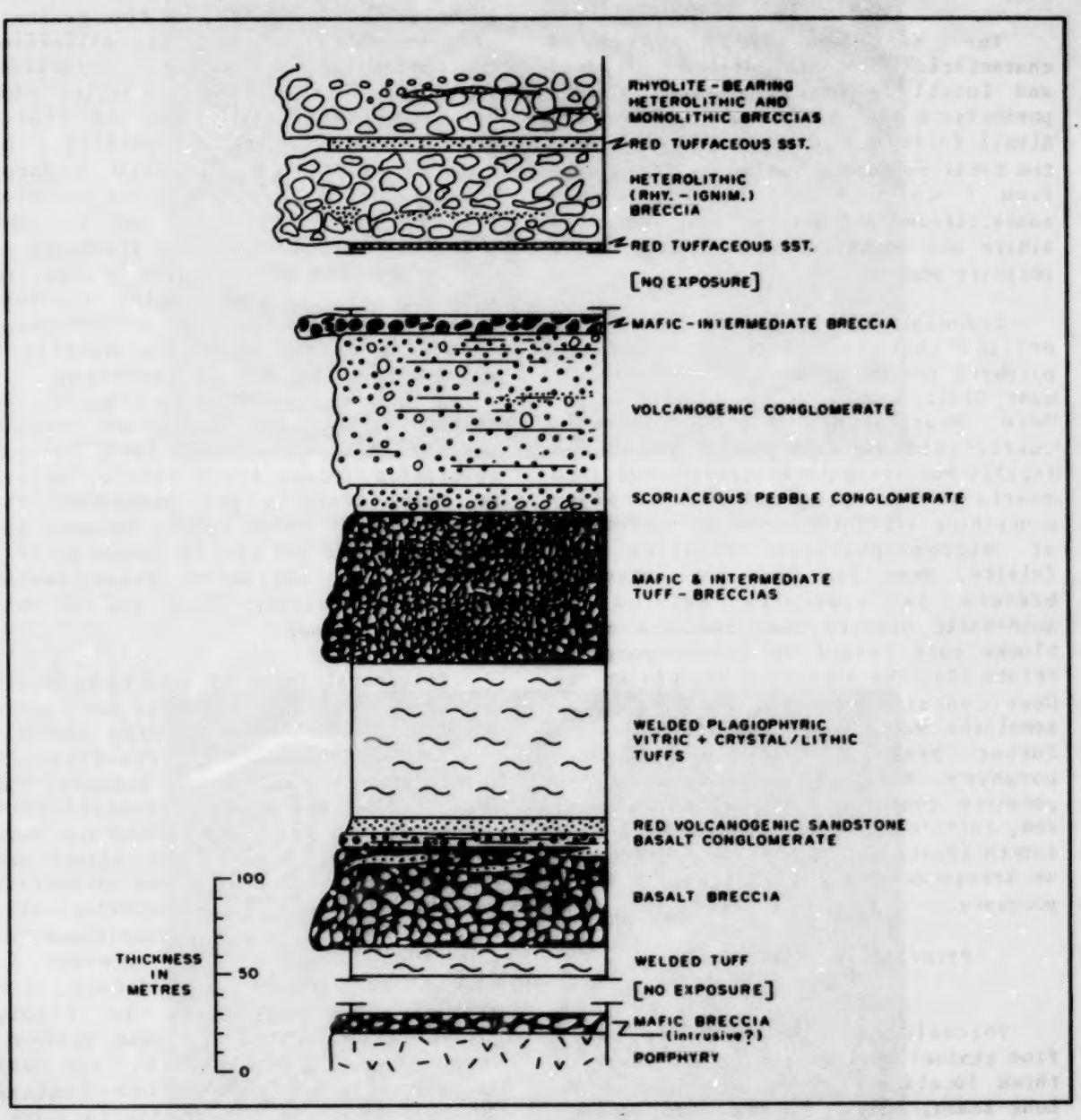


Figure 7: Composite stratigraphic section of the volcaniclastic facies of Unit 5 of the Marystown Group exposed along the Fortune Bay coast, 1M/6.

porphyry; accidental xenoliths of red sandstone and basalt are common (Plate 11).

The main porphyry phase is characterized by subhedral to rounded and locally strongly embayed quartz phenocrysts from <1 to 7 mm in diameter. Alkali feldspar, comprising over 70% of the total feldspar, varies in grain size from 1 to 4 mm, and is commonly saussuritized and hematitized. Chequered albite and perthite occur in the finer porphyry phases.

Breccia of probable intrusive origin, that is related the various porphyry phases of Unit 5a, is exposed near Bluff Head, Garden Point and Fox Cove. Near Garden Point, the main quartz-feldspar porphyry phase is rapidly but irregularly gradational into quartz-poor, plagioclase porphyry containing irregularly shaped inclusions of microporphyritic rhyolite and felsite. Near Fox Cove the intrusive breccia is spatially related to acid-basic breccia that contains mafic blocks back veined by quartz porphyry (Plate 12). The intrusive breccia at Fox Cove contains cognate and accidental xenoliths which have been injected and futher brecciated by the matrix porphyry. Near Bluff Head, the main porphyry contains rafts of hornfelsed, red, tuffaceous sandstone up to 10 m in length (Plate 13). These inclusions have an irregular contact with the adjacent porphyry.

Pyroclastic volcanic rocks (Unit 5b)

Volcanic breccia associated with fine grained, welded ash flows occurs in three localities: immediately north of Long Beach, north of Canoe Cove, and at Tilt Cove. The breccia is heterolithic; massive and spherulitic rhyolite, quartz-feldspar porphyry, welded tuff, aphyric and plagiophyric basalt, red felsite and red clastics are all important components in the block/bomb assemblage. Grain size of the breccia varies from several millimetres to 1 m, but most blocks and bombs are less than 25 cm in maximum dimension. All are chaotically dispersed in a fine grained, gray to pale brown to red, silicified quartzofeldspathic matrix. Individual fragments locally display chilled rims and show varying degrees of fluidization, flattening or welding. The breccia matrix is locally cryptocrystalline or vitroclastic and contains fine grained (0.01 - 0.1 mm) acicular and platy shards which are flattened in the plane of a primary eutaxitic foliation. The lack of sorting, together with the absence of tuffaceous epiclastic rock as either matrix or interbeds further indicates a pyroclastic origin for this breccia. The genetic relationship between the breccia and the adjacent porphyry (Unit 5a) and epiclastic facies (Unit 5c) is unclear as these contacts are unexposed. The broad spatial relationship between the volcanic rocks and the intrusion breccia suggests an intrusive relationship between the volcanic flows and the Unit 5a porphyry phase.

Fragmental rocks of uncertain origin are spatially related to the xenolithic porphyry phase. These rocks contain clasts of dominantly rhyolite to rhyodacite composition. In outcrop, the rocks resemble the xenolith-rich porphyry. Average clast diameters vary from 1 to 20 cm. Rhyolitic clasts are either aphyric or quartz and orthoclase porphyritic and are characteristically recrystallized. Aphanitic basalt and red sandstone fragments are present in subordinate amounts. In detail, the matrix of these rocks is highly variable. Locally it is fine grained, hematitized and felsitic, and may contain discontinuous flow laminae (<0.01 mm). In the porphyritic varities, rounded to embayed quartz phenocrysts and/or xenocrysts, up to 10 mm in diameter, occur in a matrix of microcrystalline quartz and feldspar. The matrix is locally coarsened during recrystallization, resulting in felsitic textures. Very rarely, the matrix to the

Plate 11: Xenolith-rich porphyry of Unit 5a of the Marystown Group. East coast of Fortune Bay, near Fox Cove.

Plate 12: Intrusion breccias of Unit 5a near Fox Cove, Fortune Bay.

Plate 13: Clastic rafts in Unit 5a porphyry. Near Bluff Head, Fortune Bay.

breccia displays weak vitroclastic and eutaxitic textures; the latter is defined by minor flattening of recrystallized quartzofeldspathic lapilli. The presence of flow alignment and eutaxitic textures suggest that at least some of the rocks may be the result of deposition due to pyroclastic volcanicity, either of ash flow or air fall origin.

Epiclastic volcanic rocks (Unit 5c)

Unit 5c consists mainly of fine to very coarse grained, dominantly epiclastic rocks and subordinate amounts of related pyroclastic rocks; it is exposed in a shallowly southeast dipping succession which outcrops between Seal Cove and Devil Brook Head. A paucity of primary orientations coupled with several exposure gaps preclude accurate thickness measurements. An approximate total thickness of between 500 and 600 m is estimated for this succession.

The basal contact of Unit 5c outcrops on the north side of Seal Cove. Here, mafic-rich volcanic breccia is in contact with quartz porphyry. The contact, much of which is obscured by a 120° trending mafic dike, is irregular and nongradational, but not clearly intrusive. There is no recognizable chilling of quartz-porphyry against the breccia. A 400 m wide pocket beach covers the contact of the mafic breccia and red, feldspar-phyric vitric-crystal welded tuff. The tuff is succeeded to the southeast by a matrix-poor, coarse grained breccia, rich in mafic detritus. The detritus is similar to mafic flows of Unit 4, and are albite, clinopyroxene, and olivine porphyritic. The proportion of matrix within the breccia increases upward in the succession. The red, scoriaceous volcanogenic sandstone of the matrix also occurs as lenses which drape over original clasts. The intersertal material is strictly clastic in origin displaying no evidence of welding, and is devoid of either volcanic shards or pumice. The above

features suggest an epiclastic origin for this breccia. The upper parts of the breccia unit are well sorted, and gradationally overlain by stratified, mafic-rich, cobble conglomerate. Approximately 4 m of red, coarse grained and immature, volcanogenic sandstone separates the conglomerate from 100 m of red, welded tuff. The sandstone is similar to the underlying clastics and consists of roughly equal proportions of plagioclase, quartz and felsic volcanic lithic fragments in an epidotized and hematized matrix with ubiquitous calcite, chlorite and epidote. The overlying welded tuff passes upward into a heterolithic mafic-rich breccia unit which fines upward into relatively well sorted gray and green, pebble to granule conglomerate.

The contact of the above succession with coarse grained, heterolithic breccia near Brown Harbour is obscured by beach deposits. At the south side of the narbour, coarse grained tuffaceous sandstone is overlain by very coarse grained volcanic breccia. The lower breccia unit is heterolithic and contains only two clast types: buff colored, epidotized rhyolite porphyry and red, welded tuff. The rhyolite clasts are quartz, orthoclase and/or albite porphyritic, and the ash flows include pumice- and lithic-rich varieties with eutaxitic foliation. The lower breccia is markedly chaotic, with grain size varying irregularly from 1 to 75 cm. The top of the lower breccia unit is marked by a 6 m wide, 18 m long red tuffaceous sandstone lens. Above this, the breccia is heterolithic, but dark red to purple rhyolite clasts (1 cm to 1 m) predominate. The rhyolite clasts are flow-banded and autobrecciated. Individual flowage bands are microspherulitic or cryptocrystalline and vary in thickness from <0.01 mm to 1 cm. Locally the rhyolite clasts are aphyric, displaying felsitic textures; the felsites may be of high level intrusive origin. Red sandstone and minor red chert occur as interstitial components; stratified red sandstone forms a 1 m thick intercalation within this breccia unit. The lack of any primary flattening due to either transport or deposition in either the blocks or matrix of the breccia, coupled with its intercalation with volcaniclastic sediment suggets an epiclastic rather than pyroclastic origin. The overall chaotic nature of the breccia is consistent with deposition by laharic flows.

The above breccia is in contact with a monomict breccia, rich in rhyolitic detritus. This breccia's matrix is comprised of rhyolitic ash-flow material, suggesting a pyroclastic origin. It is succeeded to the southeast by epiclastic breccia which in turn is overlain by red, crudely bedded, volcaniclastic sandstone and cobble conglomerate. The latter rock types occupy the highest exposed stratigraphic levels of Unit 5c.

Contact relations and correlation

Neither the stratigraphic position nor the absolute age of the volcanic rocks and porphyry of Unit 5 is presently certain. A northeast trending fault, near Bluff Head, separates typical xenolithic porphyry from a maroon, quartz porphyry containing metre-size xenoliths of red clastics and felsic pyroclastics. This porphyry is apparently gradational into a feldspar-phyric, rhyodacite porphyry to the north. Another fault, immediately south of Scott's Point, separates a similar rhyodacite from Unit 2 volcanic rocks. North of this fault the contact of the rhyodacite porphyry with mafic breccia of Unit 4 is exposed on a small point, approximately 100 m north of Garden Point. Rhyolite flows there dip moderately to the north under a 20 m wide zone of porphyritic rhyodacite. The contact is sharp and straight with no evidence of an intrusive relationship between the two. The rhyodacite is in sharp contact with the mafic breccia adjacent to the north. Neither the dip nor the facing direction at the contact is known.

The southern and eastern contacts of Unit 5 are unexposed. The irregular nature of the approximated northeast and east contact of the porphyry phase (Unit 5a) suggests an intrusive contact with the pyroclastic breccias of this unit, as well as with the volcanic rocks of Unit 2.

The pyroclastic and epiclastic breccias (Units 5b and 5c) are lithologically similar to much of the Barasway Complex (Strong et al., 1978a, b) of the Marystown Group and the Grand Beach Complex, exposed on the southern Burin Peninsula. On the basis of stratigraphic (Strong et al., 1978a, b; O'Brien, 1979) and geochronological (Krogh, pers. comm., 1979) data, the Barasway Complex is considered to be of Late Proterozoic age. The Grand Beach Complex, however, may be either Devonian (Krogh, pers. comm., 1980) or Carboniferous (Stukas, 1977) in age. At the present time, there is insufficient evidence to state with certainty which of these three periods of volcanicity the volcanic and hypabyssal rocks of Unit 5 represent.

Unit 6 - Intrusive Rocks

Introduction

Volcanic and sedimentary rocks of Units 2 and 3 are intruded by a series of granitic and granodioritic bodies that are localized in an approximately 10 km wide belt extending from the southern flank of Cape Roger Mountain in the east to the Hare Hills in the west. The dominant intrusive rock types are hornblende ± biotite granodiorite and granite and adamellites with subordinate phases of alaskite, diorite and gabbro. The granitoids in the Baine Harbour area generally form irregular shaped stocks and bosses ranging in area from 1 km^2 to 5 km^2, whereas those in the Point Enragée area form a generally continuous massif underlying approximately 50% of the northern half of the sheet. Slight compositional and textural variations, evident in the larger plutons, are interpreted to be of little genetic significance. The intrusions are all pretectonic and, although absolute ages are unknown, they are considered to be cogenetic with the main period of intrusive activity during the Late Proterozoic evolution of the Avalon Zone (Strong and Minatides, 1975; O'Driscoll, 1977a; O'Driscoll and Strong, 1979).

Lithology and contact relations

The extensive intrusive massif *(Unit 6a)* underlying an area of 60 km^2 between Powderhorn Hill and Hare Hill in the Point Enragée area is composed of equigranular and locally porphyritic textured hornblende ± minor biotite granodiorite and adamellite, and equigranular to granophyric granite. Foliated felsite and alaskite dikes, from several centimetres to 15 m in width, are intrusive into the main granodiorite/adamellite phase. Spatially associated quartz diorite occurs as isolated outcrops near the northern margin of the main massif; their genetic relationship with the latter is unclear. Widespread epidotization of plagioclase and chloritic pseudomorphs of amphibole are evidence of the subgreenschist facies metamorphism in the area. The massif is foliated at its margins but is relatively undeformed or displays only mild cataclasis in its interior.

An irregular shaped satellite of Unit 6a underlies an area of 15 km^2, south and east of Grand Jersey Cove. This granodioritic stock is coarser grained than the main massif, leucocratic, and has coarse grained hornblende gabbro associated as an areally restricted marginal phase. A narrow outcrop belt of quartz-feldspar porphyry (Unit 6b) separates this body from the main Unit 6a massif. Its contact with Unit 3 clastics is sharp; fine grained hornblende granite, granodiorite and porphyritic aplite dikes and veinlets are common at the margins of the stock. The irregular configuration of the contact and the thermal aureole, described below, may be

in part the result of an undulatory roof morphology.

Unit 6b occurs as a discontinuous series of outcrops located along the periphery of the main body of Unit 6a. Characteristic rock types are quartz-feldspar porphyry, fine grained granophyre and felsite. Although the contacts are unexposed, an overall fining in grain size away from the Unit 6a granodiorite/adamellite massif suggests that Unit 6b represents a finer grained marginal phase of the pluton. Its boundary with adjacent volcanic rocks is diffuse and is marked by centimetre to outcrop scale felsic volcanic and plutonic xenoliths. The widespread occurrence of granophyric textures coupled with the presence of fine grained microgranitic xenoliths in the coarser porphyries may be interpreted to represent successive pulses of high level intrusion in this area.

Unit 6c forms an elongate composite pluton, which is intrusive into mafic and felsic volcanic rocks of Unit 2 immediately west of the Eastern Blue Hills. Rock types include fine grained, porphyritic alaskite in the southeast, intrusive into foliated medium grained hornblende granite and subordinate equigranular hornblende gabbro, the major rock types of Unit 6c in the northwest. An isolated 1 km^2 boss of fine grained pink alaskite outcrops 2 km to the east of the main body, and is possibly related to it. Late felsite dikes cut all but the alaskitic phases of the intrusion.

The northernmost outcrops of granitoid rocks on the Baine Harbour sheet *(Unit 6d)* form the southernmost exposures of the Cape Roger Mountain Batholith (Bradley, 1962), which is well exposed in the adjacent Terrenceville area. They consist of foliated and weakly metamorphosed medium grained biotite granodiorite which is gradational into more leucocratic fine grained granodiorite and porphyritic microgranite along the southeastern pluton margin. The intrusion is cut by foliated diabase, felsite and coarse grained basalt dikes. A 2 km^2 stock of granodiorite which outcrops several kilometres to the west may be an extension of the same batholith.

Unit 6e is a series of small, irregularly shaped granitoid bodies which are locally elongated parallel to the regional foliation; they intrude Units 2 and 3 in the northern part of the Baine Harbour area. The largest of these, underlying an area of 5 km^2 south of Jacques Fontaine Gull Pond, consists of a fine to dominantly medium grained, quartz porphyritic granite. Smaller stocks of similar lithology outcrop north of the main body; dikes of similar composition occur near the eastern margin of the main granodiorite-granite massif at Powderhorn Lake. The contact with Unit 3 clastics is generally sharp; however, there is well developed net-veining of granite and arenite along the southwest contact of the intrusion.

Two small granitoid bodies outcrop between Landwash Pond and Brookside Gull Pond, approximately 8 km southwest of the main outcrop area of the Cape Roger Mountain Batholith. They consist of two major rock types: porphyritic aplite and pink, fine grained microgranite. Their map boundaries represent the outer limits of exposed intrusive rocks; their margins are diffuse and the intrusions locally contain blocks and rafts of hornfelsed rhyolite tuff up to several tens of square metres in area. The nature of the intrusive contact, coupled with the composition of the volcanic rocks, may indicate that the plutonic and adjacent volcanic rocks are comagmatic.

Mafic intrusions (Units 6f and 6g)

Aside from the minor gabbroic phases associated with the granitoid bodies described above, there is little

evidence of large scale mafic plutonism in the area. Mafic sills *(Unit 6f)* up to 350 m thick are intrusive into clastic rocks of Unit 3 south of the Grand John Fault. The sills are either massive and homogeneous or, rarely, banded parallel to strike. Although medium grained diabase is present, the majority of the sills are composed of very fine grained, plagioclase-pyroxene porphyritic metabasalt, containing individual phenocrysts up to 1 cm in length in a fine grained, locally aphanitic matrix.

At Grand Jersey Cove, Unit 6f is in fault contact with Unit 6a granodiorite; elsewhere these units are not in contact. Coarsely porphyritic basalt dikes exposed near Fish Rock Head contain rounded inclusions of quartz monzonite similar to Unit 6a. If the inclusions are related to the main period of felsic plutonism, then the intrusion of Unit 6a predates the emplacement of the mafic sills. Unit 6f sills are mineralogically similar to the mafic flows of Unit 4, to which they may serve as feeders

Diabase dikes *(Unit 6g)* cut several of the units in the map area. They are widespread in the silicic volcanic deposits of Unit 2 but rarer in the overlying sedimentary and volcanic units. Porphyritic and aphanitic metabasic dikes cut some of the foliated granitoids in the Baine Harbour area. Most dikes weather dark brown or dark gray, are foliated and strongly altered, and locally display relict/ophitic textures. Individual dikes range in thickness from a few centimetres to 10 metres. In Unit 2, diabase dike swarms (>50% dikes) are present in felsic volcanic rocks near the contacts with adjacent mafic flows, indicating that the dikes may locally serve as feeders to these flows.

The porphyritic dikes are less common; they contain phenocrysts of plagioclase and/or pseudomorphed pyroxene averaging 2-3 mm in length. The coarsely porphyritic foliated dikes near the south flank of Cape Roger Mountain contain epidotized plagioclase phenocrysts up to 1.5 cm long.

MUSGRAVETOWN GROUP (Unit 7)

Definition and distribution

The name Musgravetown Group was first used by Hayes (1948) in reference to a series of arkosic sediments and volcanic rocks which overlie the Connecting Point Group and which are overlain by basal Cambrian quartzites of the Random Formation in the Bonavista Bay - Trinity Bay area of eastern Newfoundland. Jenness (1963), Anderson (1965) and McCartney (1967) traced rocks of this group from Bonavista Bay to Placentia Bay and southward along the eastern coast of the Burin Peninsula. In the latter area, O'Driscoll (1978) and O'Driscoll and Muggridge (1979) also included in this group a sequence of dominantly marine clastic sediments which is conformably overlain by the Random Formation in the Harbour Buffett and Merasheen areas. The marine clastics extend into the Baine Harbour area and are markedly similar to the above sequence in terms of lithology, facies distribution, and their stratigraphic position relative to the Random Formation and other Cambrian rocks. On the basis of these similarities, the clastic rocks underlying the Paradise Peninsula and nearby islands in the Baine Harbour area are assigned to the Musgravetown Group *(Unit 7)*. Also included in this group are the mafic volcanic rocks which outcrop in the easternmost part of the Baine Harbour area at White Sail Head. These volcanic rocks are continuous into the more extensive basalt succession in the Harbour Buffett area. There, O'Driscoll and Muggridge (1979) correlated the same volcanic sequence with the Bull Arm Formation of the Musgravetown Group (McCartney, 1967).

Marine clastic rocks which outcrop on Jude Island and Flat Islands in the southern part of the Baine Harbour area

were previously assigned to the Rock Harbour Group of Strong et al. (1978a) and by O'Brien (1978). The marine clastic rocks exposed on these islands are lithologically and stratigraphically similar to the succession on the Paradise Peninsula and are here reassigned to the Musgravetown Group. It is here proposed that the name Rock Harbour Group be dropped. East of the Paradise Sound fault, small inliers of Late Proterozoic clastics disconformably overlie the Marystown Group and are locally faulted against it. These clastics are here interpreted as time-stratigraphic facies equivalents to the Musgravetown Group exposed to the east.

Rocks of the Musgravetown Group are exposed in four geographically distinct areas within the study area; the sequence in each of the areas is described below. Composite stratigraphic sections of the group are shown in Figure 8.

Paradise Peninsula

A sequence of fine to coarse grained, dominantly marine clastic rocks, here assigned to the Musgravetown Group, underlies much of the area east of the trace of the Paradise Sound Fault, in particular, the Paradise Peninsula and Marticot and Long Islands to the south. These sediments are faulted against mafic volcanic rocks and are conformably overlain by quartzite of the Random Formation. The contacts of the Musgravetown Group with fossiliferous Cambrian strata on Long Island and at Southeast Bight are faulted. A minimum of 1,900 m of stratigraphic section is exposed on the eastern shore of Paradise Sound.

Lithology

Mafic volcanic flows and pyroclastics *(Unit 7a)* are in fault contact with the sedimentary facies of the Musgravetown Group on the eastern side of White Sail Head. The basalt-sediment contact in the adjacent Merasheen area is conformable and the sedimentary rocks overlie basalt. The volcanic rocks of Unit 7a include red and purple mafic agglomerate and tuff; the agglomerates are locally coarse grained and contain blocks up to 50 cm in diameter. Light green, amygdaloidal basalt flows are subordinate here, but much more extensive to the northeast (O'Driscoll and Muggridge, 1979).

The clastic rocks of the Musgravetown Group in this area can be subdivided into four main lithostratigraphic units. The lowermost and most extensive of these *(Unit 7b)* is well exposed on the southern part of the peninsula, between Red Cove and White Sail Head and on the limbs of a syncline at Channel Harbour. The diagnostic rock types of this unit are massive to well bedded, medium to coarse grained green sandstone, pebbly sandstone and siltstone; lesser amounts of green conglomerate and laminated siltstone are locally developed near its base.

The lowest stratigraphic levels of Unit 7b are exposed at Butter Cove and at a locality approximately 1 km north of Channel Harbour. At Butter Cove, several tens of metres of poorly bedded, cobble and fine grained boulder conglomerate are juxtaposed with massive mafic flows of Unit 7a. The fault is interpreted to have had minor displacement because approximately 2 km to the north, in the adjacent Merasheen map area, the same contact is conformable (O'Driscoll and Muggridge, 1979). The lowermost conglomerate grades rapidly upward into thinly bedded siltstones, which are conformably overlain by a thick succession of well bedded sandstone and massive to well bedded, pebbly sandstone. Near Channel Harbour, the lower conglomerate beds are absent and mafic flows and mafic volcanic breccia are overlain, with no obvious structural break, by thick, regularly bedded sandstone with thin silty interbeds. The well bedded sandstone is coarse grained and green in color, and commonly interbedded with

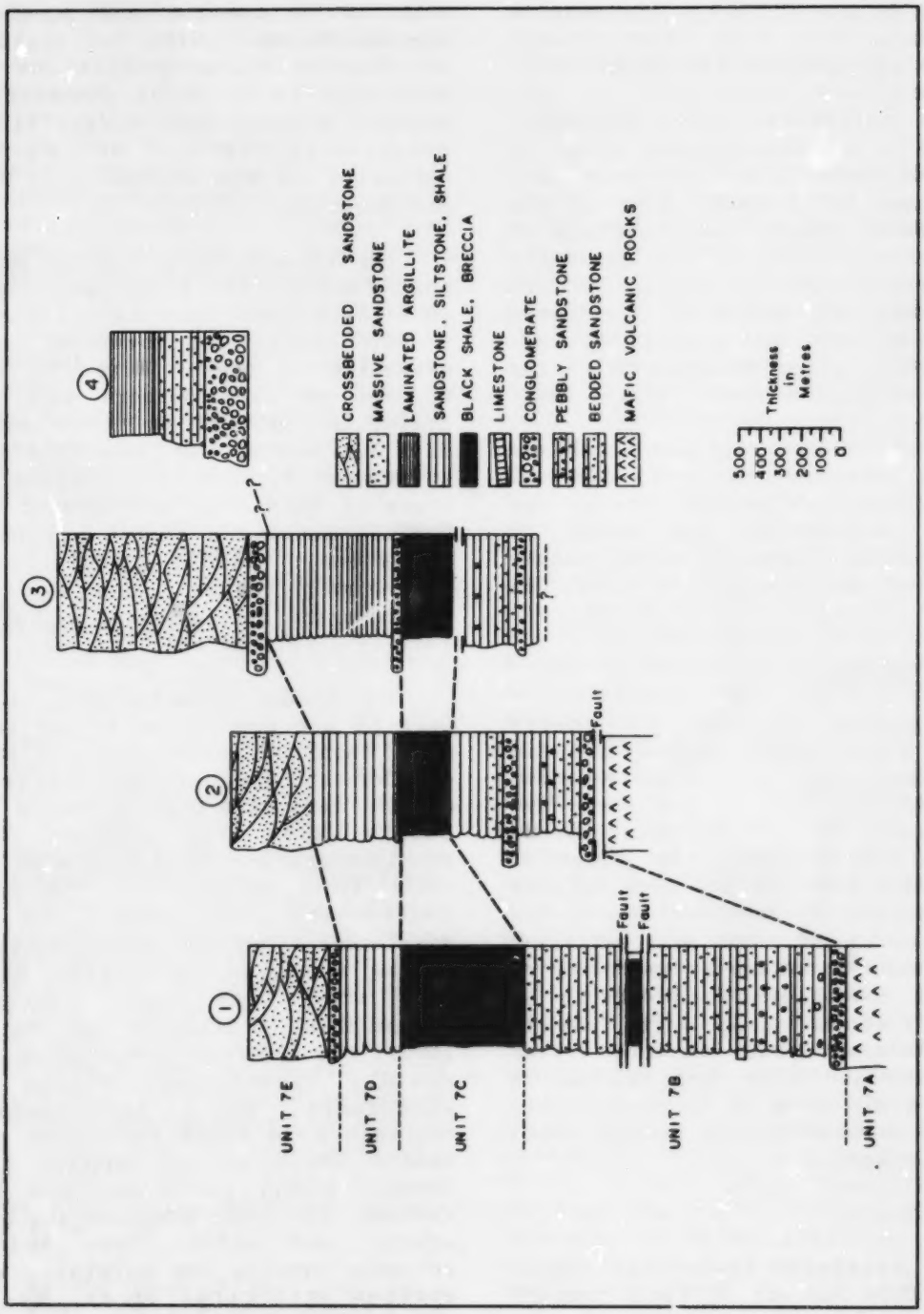


Figure 8: Composite stratigraphic sections of the Musgravetown Group from (1) Davis Cove, (2) the Paradise Peninsula, (3) Jude Island, and (4) Flat Islands. The Davis Cove section was measured in the northerly adjacent Harbour Buffett (1M/9) map area (O'Driscoll and Muggridge, 1979).

light to dark gray, locally convoluted, siliceous siltstone. Only the uppermost few centimetres of the individual sandy beds are graded. The proportion of siltstone varies throughout the succession; locally, siltstone predominates. In the uppermost parts of the succession, the sandstone is more thickly (0.6 - 1 m) and regularly bedded, and characteristically ungraded. Coarse grained sandstone and pebbly sandstone and conglomerate occur as interbeds within Unit 7b sandstones between Paradise and Eastern Head.

Unit 7b is overlain conformably by a fine grained gray to black shale - siltstone facies *(Unit 7c)*. These rocks are exposed at Beckford Cove and at several localities between Monkstown (1M/9) and Channel Harbour. The contact of Units 7b and 7c is exposed at Channel Harbour and a locality 3 km to the north (1M/9). Black pyritiferous shale, black flaggy siltstone and sandstone-shale breccia overlie Unit 7b sandstone in a synclinal core at Channel Harbour. Elsewhere in Paradise Sound, the shale and siltstone forms discontinuous beds and lenses, intercalated with sandstone. The degree of disruption of the beds is highly variably. Individual beds, rarely greater than 10 cm in thickness, may extend for several metres. In the more intensely slumped parts of Unit 7c, angular to subrounded sandstone fragments in a shaley matrix are all that remain of the sandy beds. At Beckford Cove, the sandstone-shale breccia and conglomerate predominate and all evidence of original stratification is missing. Throughout much of the Paradise Peninsula (1M/7, 1M/8, 1M/9), equivalents of Unit 7c are spatially associated with faulted slivers of black, polymictic, shaly matrix breccia and conglomerate. At Beckford Cove the breccia contains large clasts of leucogranite and marble. It is conformably and gradationally overlain by sandstone-shale breccia.

Unit 7c is conformably overlain by laminated siltstone and thinly bedded gray sandstone and siltstone *(Unit 7d)* near Beckford Cove. At this locality the succession is faulted against underlying Unit 7b pebbly sandstone. The most complete section of Unit 7d is exposed on the east shore of Paradise Sound, between UTM coordinates 836541 and 847552.

The lowermost part of the continuously exposed section of Unit 7d, faulted against fine grained laminated siltstone, is composed of light green siltstone with interbeds of fine grained sandstone. In the lowermost several metres of this section, crossbedding and scouring features are rare and graded beds with flame structures are common. These rocks are succeeded to the southwest by thinly bedded (1-5 cm) coarse siltstone containing complete and partial Bouma sequences. Approximately 120 m above the base of this sequence, the siltstone is overlain by a thin, green, fine grained conglomerate, which passes upward into massive, fine to coarse grained sandstone. The latter is overlain by 15-20 m of poorly sorted, clast-supported and locally imbricated conglomerate containing scoured interbeds (3 cm - 1 m) of coarse grained sandstone. The conglomerate contains up to 10% previously deformed detritus; the most common deformed clasts are foliated equigranular to locally coarsely porphyritic textured granite and psammite (Plate 14). Overlying and interbedded with the conglomerate is fine to medium grained, quartz-rich sandstone which grades upward into thinly bedded sandstone, then into argillite. This dominantly sandy facies attains a maximum thickness of 50 m. Fine grained sandstone overlies the argillite; the uppermost 10 m of the sandstone contains rip-up clasts of the underlying argillite. The overlying argillite is gradational upward into approximately 150 m of well bedded (5 mm - 4 cm) siltstone. Individual beds are crossbedded, graded and parallel laminated.

Plate 14: Foliated detritus in conglomerate bed of Unit 7d of the Musgravetown Group, Paradise Sound.

Unit 7e conformably and gradationally overlies Unit 7d and is well exposed immediately southwest of it, on the east shore of Paradise Sound. The turbidite facies siltstone of Unit 7d is overlain by an approximately 25 m thick sequence of pebbly, arkosic sandstone forming the base of Unit 7e. The top of the arkosic sequence is marked by a red, medium grained, angular and monomict sedimentary breccia, which is in turn conformably overlain by a sequence of gray and green, fine grained sandstone with shaly interlaminae. A distinctive, medium grained, purple sandstone bed occurs several metres above the base of the sandstone-shale unit. Above the red sandstone bed, the interbedded sandstone-siltstone sequence contains four 5 to 30 cm thick quartzite beds. The sandstone at this level in the succession is characteristically muscovite-bearing, quartz-rich, and graded; the interbedded siltstone beds are rippled. The sandstone coarsens upward into arkosic pebbly sandstone which is overlain by 5 m of hematitic red sandstone with thin red shale interbeds. This passes upward into thinly laminated siltstone and micaceous sandstones, containing three thin (<5 cm) quartzite beds approximately 30 m above the top of the red sandstone unit. The lower quartzite bed marks the base of the Random Formation. At this locality, the Random Formation passes upward into fossiliferous Lower Cambrian strata.

Unit 7e is also exposed at Long Island and Southeast Bight. In both areas it is dominated by red and gray arenaceous sandstone, pebble conglomerate and quartzose sandstone.

Contact relations

The base of the Musgravetown Group is unexposed in the Paradise Peninsula section. Possibly the lowest stratigraphic levels of the clastic sequence are exposed at Butter Cove, where coarse grained, pebble to boulder conglomerates are in fault contact with vesicular mafic flows of Unit 7a, which are presumably equivalent to the mafic volcanic rocks of the basal Musgravetown Group (Bull Arm Formation) to the north (O'Driscoll, 1978; O'Driscoll and Muggridge, 1979). In Presque, equivalents of Unit 7b sediments overlie these mafic volcanic rocks conformably.

Jude Island

Approximately 2000 m of marine clastic sediments are exposed in a coarsening upward, northwest dipping sequence on Jude Island, in the southern part of the Baine Harbour area. Neither

the base nor the top of the succession is exposed at this locality. The clastic rocks can be divided into four facies, which are essentially equivalents of Units 7c through 7e on the Paradise Peninsula.

Lithology

The southeasternmost and stratigraphically lowest facies is well exposed at Hay Cove and Eastern Cove. It is characterized by black shale and fine grained, black siltstone with disrupted and slumped interbeds and scattered clasts of light and dark gray, coarse grained siltstone and fine grained sandstone. Subordinate amounts of black pyritiferous shale and monomictic and polymictic sedimentary breccia are present; the breccia contains rare limestone clasts. The black shale and breccia are intercalated with the slumped siltstone-shale lithology; both contain rare interbeds of dark gray, matrix-supported conglomerate. The breccia contains fine to coarse grained, subrounded to angular blocks of shale and sandstone, and, much more rarely, limestone and basalt. All of the above rock types are intruded by fine grained diorite and coarse grained gabbro dikes. This facies is considered to be equivalent to *Unit 7c* of the Paradise Peninsula section.

The above facies is succeeded to the northwest by approximately 10 m of conglomerate, exposed on the northern shore of Hay Cove and Eastern Cove. In the latter locality, only the lowermost conglomerate is relatively massive, and it contains well rounded felsic volcanic, clastic and, rarely, plutonic clasts. This conglomerate is directly overlain by well bedded (30 cm) matrix-supported conglomerate containing thin, regular interbeds of dark gray sandstone and pebbly sandstone.

The conglomerate facies is conformably overlain by an approximately 700 m thick sequence of well bedded gray and green sandstone and gray siltstone, well exposed on the west side of the island, between Hay Cove and Jude Harbour (Plate 15). The lower half of the sequence is very regularly bedded, with little systematic variation in the sand:silt ratio. On average, the siltstone beds are 3 to 8 cm thick and are spaced 20 to 30 cm apart within the sandstone. Approximately halfway up this facies, several 2 to 3 m zones of more thinly bedded gray sandstone and siltstone are present within the rhythmically bedded sequence. This

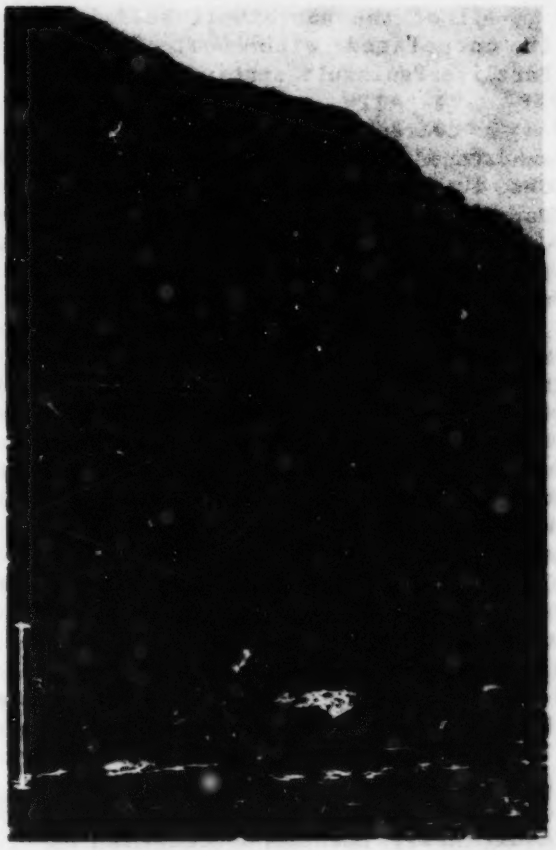


Plate 15: Rhythmically bedded siltstone of Unit 7d of the Musgravetown Group, near Hay Cove on Jude Island.

thinly bedded, fine grained sandstone locally displays parallel lamination and cross-lamination; the beds are characterized by sharp erosional tops. Basal loading structures are preserved at several localities. Above this zone, there is a thickening of the sandy beds to an average of 40 to 60 cm. The silty interbeds are finer grained, but their thickness remains relatively constant. At this level, the sandstone contains rare, ovoid nodules and thin wispy bands of brown calcareous sand. It is succeeded to the west by rhythmically bedded sandstone and siltstone.

All of the above well bedded facies is correlated with *Unit 7d* of the Paradise Peninsula section.

A coarser grained, poorly bedded, sandstone facies, here correlated with the lower parts of *Unit 7e* of the Paradise Peninsula section, occupies the uppermost stratigraphic levels of the succession on Jude Island. The base of this facies is marked by a red, coarse grained, matrix-supported pebble to boulder conglomerate. Its contact with the underlying rhythmically bedded facies is sharp and conformable with no scouring effects evident. The conglomerate, which reaches a maximum thickness of approximately 20 m at Round Head, is poorly sorted and polymictic; maximum clast diameter is approximately 30 cm. Rhyolite, rhyolite porphyry and red and green clastics dominate the detrital assemblage.

On the north side of the island, the basal conglomerate fines rapidly upward into granule conglomerate and reddish-gray, cross-laminated, quartz-rich, coarse grained sandstone. However, at Round Head, the basal conglomerate is overlain by green sandstone, which is interbedded with pale red sandstone and red siltstone. Above the interbedded zone, pale red sandstone predominates and contains thin interbeds of green granule conglomerate. This coarser grained, poorly bedded facies is characterized by immature, gray, quartz-rich sandstone and light gray arenite. The sandy beds are cross-laminated, locally containing cobble conglomerate in the foresets. The sandstone in the lower parts of this facies forms graded, 10 to 20 cm thick beds. Pebble conglomerate interbeds are common throughout this part of the succession.

The base of the Musgravetown Group is unexposed on Jude Island.

Flat Island

A coarse to fine grained marine clastic sequence, tentatively correlated with the Musgravetown Group, outcrops in the southernmost parts of the Baine Harbour map area. Best exposures occur along the south coast of Davis Island and all of Coachman, Durdle, and Woody Islands. This succession fines upward and has an approximate thickness of 700 m.

Lithology

The base of the sequence in this area is a massive boulder conglomerate, outcropping on the south coast of Davis Island. The conglomerate is gray and green, massive, poorly sorted and clast-supported; the detrital assemblage is dominated by well rounded clasts of felsic volcanic and hypabyssal intrusive lithology. The conglomerate gradually becomes finer grained to the south, which is the direction of overall younging for the sequence in this area. The southern exposures of this unit contain discontinuous beds and lenses of coarse grained sandstone and granule to pebble conglomerate. These coarse grained clastics grade upward into a sequence of sandstones, locally pebble-rich, which are rapidly succeeded southward by laminated and convoluted fine grained siltstone and argillite outcropping on the southernmost tip of Davis Island and nearby Woody Island. The fine grained facies is dominated by interlaminated siltstone and mudstone and is characterized by locally intense soft sediment deformation (Plate 16).

Plate 16: Contorted bedding in siliceous siltstone near the top of the Musgravetown Group succession exposed on Davis Island, Placentia Bay.

Correlation of the above stratigraphy with the sequence present on the numerous islands immediately to the southwest is tenuous due to numerous faults and exposure gaps. Conglomerate and interbedded pebbly sandstone predominate on these islands, with lesser amounts of argillite occurring at several structural levels within the sequence.

Medium to coarse grained sedimentary breccia outcrops on the southern part of Coachman Island. It overlies fine grained conglomerate containing irregular sandstone lenses, the largest of which is a 1 m thick zone near the base of the breccia unit. Coarse grained, locally pebbly sandstone and gray siltstone serve as a matrix to angular, chaotic, dominantly argillaceous blocks, up to 1 m long. Blocks of coarser grained clastics are notably rare, and volcanic and plutonic detritus is absent. The breccia may represent slumped equivalents of the argillite exposed on Woody Island.

Basal relationships

Hiscott (1981) suggested that conglomerate, here assigned to the basal Musgravetown Group, lies with profound angular unconformity on mafic volcanic rocks of the Burin Group in the Flat Islands area. We support this hypothesis for reasons outlined earlier, but we feel that the exposures of the unconformity described by Hiscott are equivocal, and that this contact is faulted. The surface of the unconformity is unexposed on Davis Island, and the same regional foliation occurs in conglomerate above the unconformity and in the breccia, conglomerate and black slate assigned by Hiscott (1981) to the Burin Group below. The situation at the Coachman Island contact is more problematic. Some interdigitation of clastic and volcanic rocks occurs at this locality, indicating the conglomerate there may represent part of the Burin Group succession.

Island Pond (1M/6)

Aside from the main areas discussed above, Latest Proterozoic clastics occur in several small, isolated synclinal or down-faulted outliers. These Late Proterozoic outliers, here included in the Musgravetown Group, consist of red, green, and gray micaceous sandstone and quartz sandstone, and could possibly be equivalent the top of the Musgravetown

Group (Unit 7e) on the Paradise Peninsula. The sequence is best exposed in a synclinal keel immediately northwest of Island Pond in the southeastern part of the Point Enragée map area. Smaller remnants, overlain by Lower Cambrian strata, are exposed on the west side of Paradise Sound, Long Island and the western headland of Cape Roger Bay; these are also included in the Musgravetown Group.

At Island Pond, Late Proterozoic red, locally crossbedded sandstone and fissile shale are directly overlain by gray micaceous siltstone containing thin conglomerate beds rich in felsic volcanic detritus. On the north limb of the syncline, quartz- and felsite-pebble conglomerate separates the volcanic rocks from a sequence of red shale that is overlain conformably by micaceous gray sandstone containing thin beds of quartz sandstone and orthoquartzite. The latter may be equivalent to the Random Formation (Walcott, 1900) described below.

The Late Proterozoic exposures at Cape Roger Bay and Long Island consist of red and gray arenaceous sandstone, pebble conglomerate, quartzose sandstone and quartzite which are faulted against older Late Proterozoic volcanic rocks and are locally conformably overlain by fossiliferous Lower Cambrian strata.

The base of the Musgravetown Group at Island Pond is marked by a thin, red, volcanogenic pebble conglomerate that disconformably overlies reworked felsic pyroclastics of the Marystown Group on the northeast end of the syncline's southeastern limb; elsewhere the southeastern limb is down-faulted against adjacent Marystown Group volcanic rocks. On the north limb of the syncline, massive felsite and densely welded and reworked lithic tuff are overlain by the basal pebble conglomerate of the Latest Proterozoic sedimentary succession.

RANDOM FORMATION (Unit 8)

The name Random Formation was originally used by Walcott (1900) to describe the "sandstones, quartzitic sandstones and sandy shales" overlying the Musgravetown Group in western Trinity Bay. Christie (1950) redefined the formation, limiting it to those beds below Lower Cambrian (*Callavia*-zone) green and red slate and limestone and above clastic or volcanic rocks of the Musgravetown Group. That Christie's (1950) definition is inadequate is evident from the fact that not only the Random Formation, but also the red and green shale and limestone of the Bonavista and Smith Point Formations stratigraphically underlie *Callavia*-zone fossils. His definition was revised by Jenness (1963) to include those rocks above the Musgravetown Group and below strata bearing *Coleoloides*-zone fossils.

Rocks of similar lithology and stratigraphic position have been identified at several localities in the Baine Harbour area, namely: Sound Island, Paradise Sound, Southeast Bight, Long Island and Red Cove. The quartzose clastics, described above, that outcrop at Island Pond in the Point Enragée area, may also include lithostratigraphic equivalents of the Random Formation.

Although interrupted and repeated by faults and folds, the Late Proterozoic - Cambrian sequence at Long Island contains the best exposed section of Random Formation in the study area. The base of the formation on Long Island is drawn at the bottom of the lowermost orthoquartzite bed that overlies Late Proterozoic red and green siltstones and sandstones of the Musgravetown Group (Unit 7e) and that is interbedded with micaceous siltstone. The lower part of the Random Formation consists of three main quartzite beds of 1 m maximum thickness, interbedded with gray siltstone. The upper quartzite bed is overlain by laminated light and dark gray shale, which passes conformably

upward into a green shale sequence characteristic of the lower Cambrian Bonavista Formation. The green shale is overlain by lower Cambrian red and green shale and pink limestone.

The Random Formation is in conformable contact with the underlying Proterozoic succession at only one locality in the map area. Approximately 2 km north of Southeast Bight, the lowermost of three thin Random Formation quartzite beds conformably overlies Musgravetown Group clastics (see Unit 7).

UNDIVIDED LOWER CAMBRIAN (Unit 9)

Lower Cambrian, shallow marine clastic rocks, outcrop in only the western part of the Baine Harbour area; there they are spatially associated with the Musgravetown Group and its equivalents. Fault-bounded remnants of Lower Cambrian clastics are preserved on the east side of Paradise Sound, Jude Island, Long Island and between Red Cove and Southeast Bight on the southern end of the Paradise Peninsula.

The successions exposed at Paradise Sound and Jude Island are dominated by red, laminated siltstone and shale with limy concretions, and green siltstone with oncolitic limy beds (Plate 17). On Long Island, a minimum thickness of 150 m of Lower Cambrian strata is exposed in a southeast plunging syncline. A tightly folded sequence of red and green shale with minor limestone beds and nodules directly overlies the upper red and green shale of the Bonavisita Formation. The shale sequence is succeeded by two algal limestone beds, rich in hyalithids and oncolites, interbedded with red shale. The upper limestone bed is overlain by a minimum of 30 m of red shale containing pink limestone nodules. The part of the above succcession which underlies the algal limestone beds may be correlative to the Bonavista Formation (Van Ingren, 1914) of the Lower Cambrian *Coleoloides*-zone. The limestone beds and overlying red shale may be

Plate 17: Lower Cambrian red shales with oncolitic and nodular pink and gray limestone beds. North shore of Jude Island.

equivalent to the Smith Point Formation (Walcott, 1900) and Brigus Formation (Van Ingen, 1914) respectively.

The Lower Cambrian succession on the southwestern tip of the Paradise Peninsula is disrupted by numerous normal and thrust faults. The faulting and repetition of units by folding precludes the establishment of the detailed Lower Paleozoic stratigraphy in this area. The base of the succession is faulted against Late Proterozoic quartzose clastics (Random Formation?) and consists of red and gray siltstone

and shale with calcareous nodules that increase in frequency stratigraphically upward. These rocks are succeeded upward by red, purple and gray siltstone, which grades upward into gray siltstone with calcareous concretions, red shale and siltstone with limestone nodules and a 1.5 m thick, pink algal limestone bed, possibly equivalent to the Smith Point Formation (Plate 18). Overlying the limestone is a thin sequence of red siltstone with nodular limestone interbeds, which is in fault contact with red and gray shale of unknown stratigraphic position. The nodular limestone interbeds are fossiliferous and yield *Callavia*-zone trilobites (B.A. Greene, personal communication, 1979). Its stratigraphic position above fossiliferous limestone, coupled with the presence of *Callavia*-zone fossils, indicates that this red siltstone sequence is equivalent to the Brigus Formation.

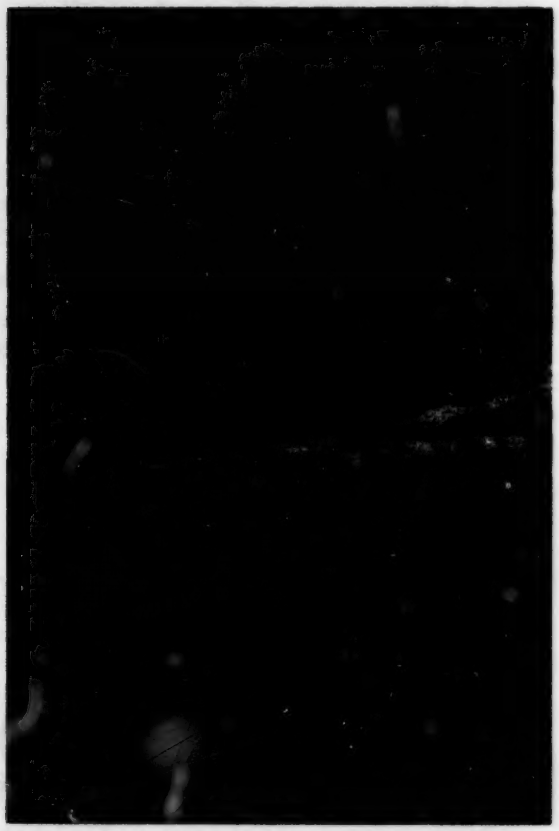


Plate 18: Continuous Lower Cambrian section on the southern tip of the Paradise Peninsula. Limestone beds occur in the lower parts of the section.

DEPOSITIONAL AND TECTONIC HISTORY

DEPOSITIONAL HISTORY: a summary

The pillowed and massive mafic flows and associated tuffaceous and clastic rocks of the Burin Group (Unit 1) are interpreted as evidence of a period of submarine volcanism and sedimentation early in the evolutionary history of the area. If the correlation of these volcanic rocks with the Burin Group of the southern Burin Peninsula (Strong et al., 1975, 1978a,b) is correct, then this volcanism, dated at ca. 760 Ma (Krogh, 1982), predates the major period of Proterozoic subaerial volcanicity by almost 150 Ma (see below). In the Burin area, the submarine volcanic rocks display strong chemical affinities with ocean floor tholeiites; this led Strong et al. (1978a) to interpret these rocks as remnants of oceanic crust.

The next major stage in the Proterozoic evolution of the area was dominated by widespread subaerial volcanism. The volcanic, clastic and granitoid rocks of the Marystown Group (Units 2 through 6) represent a period of extensive, dominantly subaerial volcanism, comagmatic plutonism and subaqueous to terrestrial clastic sedimentation. These rocks and their on-strike equivalents are disconformably overlain by fossiliferous Cambrian successions; recent U-Pb radiometric studies (Dallmeyer, 1980) bracketed the time of this volcanicity between 633 Ma and 584 Ma. These dates strongly suggest a major evolutionary break with the 760 Ma formation of oceanic basalts of the Burin Group and its equivalents.

Unit 2 mainly represents widespread felsic, pyroclastic volcanic activity and associated mafic volcanism. The common occurrence of welded tuffs indicates that ash-flow volcanicity was a major process active at this time. The equally extensive unwelded tuffaceous deposits may be the result of air fall deposition, but also represent, in part, unwelded portions of larger ash-flow sheets. It should be noted that the concept of single ash flows, developed by Smith (1960), is not directly applicable to large volcanic fields such as that represented by the Marystown Group. In such areas, ash-flow volcanicity results in the production of compound flows, within which it is possible to have combinations of all lithologic variations seen within a typical, single cooling unit.

It is not possible, with the available information, to establish the significance of the coarse grained agglomerate and related pyroclastic breccia that occur throughout Unit 2. These rocks are intimately associated with the ash-flow deposits and display similarities to basal pyroclastic flow deposits and co-ignimbrite lag deposits (Wright and Walker, 1977); the latter have been interpreted as indicating proximity to a volcanic vent or caldera centre. The documented spatial association of pyroclastic and epiclastic breccias also indicate proximity to a source area, as volcanic mudflows or lahars are commonly localized on the slopes of and adjacent to active volcanic edifices (e.g. Fisher, 1960, Mullineaux and Crandell, 1962).

Tuffaceous rocks and related epiclastic beds with abundant sedimentary structures are present in Unit 2, in particular near the contact with Unit 3. The occurrence of scouring and trough cross-stratification indicates reworking by sedimentary processes, possibly related to fluvial systems. The arenaceous and generally immature character of these rocks suggests relatively short distances of transport. Their association with subaerial ash-flow and minor air-fall deposits further suggests a terrestrial origin for these rocks. In the central parts of the Point Enragée area, these epiclastics are interbedded with vesicular, locally oxidized basalts, further indicating terrestrial origin.

The clastic rocks of Unit 3 in the Point Enragée area represent a local waning in volcanicity in the area. They are moderately to poorly bedded, submature to immature, locally graded, and characteristically cross-stratified. The lower parts of this succession bear resemblance to products of fluvial deposition in that they are coarse grained and trough crossbedded, and locally fine upward. The finer, relatively mature clastics which predominate in the upper parts of Unit 3 are interpreted to reflect deposition in relatively quiet water environment, related to either fluvial channels or shallow marine basinal deposition. The paucity of graded beds, parallel laminations and argillaceous sediments suggests that deposition via turbidity currents was unlikely. The fining upward character of the northern exposures of this unit is consistent with fluviatile or overbank deposition. The reddening of the highest part of the succession may reflect terrestrial influence in the sediment from an encroaching shoreline.

The latest stages of volcanicity in the region occurred in subaerial conditions, as is evidenced by the almost total lack of any subaqueous clastics within Units 4 or 5. Mafic rocks of Unit 4 are highly vesicular, locally intercalated with red, terrestrial clastics, and show little evidence of subaqueous reworking. Likewise, Unit 5 displays no features indicating either subaqueous deposition or reworking. The widespread occurrence of coarse agglomerates coupled with the spatial association of very coarse grained laharic breccias suggests a volcanic source area near the present

exposures of this unit. The presence of a high level, intrusive felsic porphyry and acid-basic intrusion breccias is consistent with such a model for Unit 5 volcanism.

The volcanic rocks of the Marystown Group are similar in many respects to the volcanic deposits of the extensive, subaerial Cenozoic and Mesozoic calderas of the southwestern U.S.A. (e.g. Lipman et al., 1972; Lipman and Mehnert, 1975; Chapin and Seager, 1975), which were produced in an extensional tectonic environment. The widespread occurrence of subaerial pyroclastic deposits within the Marystown Group is in keeping with such a model of extensional tectonics. In such a model, Marystown Group volcanicity would be related to caldera centres, the roots of which may be exposed in the granitoids (Unit 6) and porphyries that intrude it. It should be noted, however, that similar deposits, of characteristically lesser extent, occur in ensialic arc and volcanic island settings (see Review of Regional Tectonic Evolution).

Whereas the Late Proterozoic evolution of the area west of the Paradise Sound Fault is characterized by widespread subaerial volcanicity, the younger Proterozoic rocks occurring east of this structure, represent an extensive period of marine sedimentation.

Exposures of the lower parts Musgravetown Group (Unit 7b) on the Paradise Peninsula are dominated by well bedded, graded sandstone and shale. The sandstone-shale succession includes "classical" proximal turbidite (Walker, 1967) or AE turbidite (Bouma, 1962), and massive, delay graded sandstone; these may be grouped respectively into turbidite facies C and D of Walker and Mutti (1973), both of which are characteristic of mid-(submarine)-fan deposition environments. The presence of pebbly sandstone (facies A-Y of Walker and Mutti, 1973) is consistent with such a depositional environment. The overlying shales of Unit 7c could be deposited in middle or inner fan areas, given rapid dilution of turbidity currents. The sandstone-shale breccia of this unit may indicate a degree of downslope movement. Nevertheless, the characteristically ruptured bedding strongly resembles ball-and-pillow structures and may have resulted from vertical displacement (cf. Potter and Pettijohn, 1963) rather than slumping, or the combination of lateral and vertical displacement. The environment of deposition of Units 7d and 7e, and the significance of the overall facies association with the underlying units, are uncertain. Units 7c, 7d, and 7e appear to represent an overall, albeit rapid, transition from turbidite to shallow water sediments (cf. Walker, 1966). The association of quartzite interbedded with red terrigenous sandstone indicates shallow shelf or shoreline environments and terrestrial input, related to the onset of the Late Proterozoic transgression. This transition may be related to the progradation of a submarine fan, but if so, then the processes causing such a rapid progradation are unclear.

The exposures of the Musgravetown Group on Jude Island are dominated by well bedded siltstone and sandstone. The presence of sharp based and sole marked sandstone and parallel and cross-laminated siltstone beds with sharp tops, together with the abundance graded sandstone shale beds in this succession is strongly suggestive of turbidite deposition. The interbedded pebbly sandstone and conglomerate beds within this sequence may also be interpreted as being of deep water origin, given their intimate association with the turbidite facies. The massive, ungraded sandstone beds in the succession may result from immature turbidity currents in which no size segregation has occurred. The coarser grained, cross-laminated sandstone at the top of the Jude Island succession is interpreted to represent a waning regression associated with the filling of the depositional basin.

In the Flat Islands area, the Musgravetown Group represents a fining upward sequence of conglomerate, pebbly sandstone, sandstone, siltstone, argillite and shale. Aside from the conglomerates, which are characteristically structureless, this sequence displays some features which suggest deep water sedimentation. The sandstone deposits are graded, stratified and scoured and occur in association with parallel laminated, sharp based siltstone and argillite. The slumped argillite and olistostromal breccia exposed on Coachman Island may be the result of debris flowage on submarine slopes. Hiscott (1981) interpreted the conglomerate facies in this area in terms of a submarine slope channel model.

In general, it appears that the Musgravetown Group exposed in the map area is the result of marine deposition mainly by turbidity currents. There is no evidence of contemporaneous volcanicity anywhere within this succession above the basal volcanic unit (7a). The upper parts of this group may record deposition in shallow marine conditions. The presence of quartzite indicates a high energy shoreline environment of deposition in the latest Proterozoic evolution of this part of the area.

The latest Proterozoic is represented by a thin succession of red and minor green, fine to coarse grained clastic and reworked volcaniclastic rocks. The overall fining of this sequence from conglomerate through micaceous sandstone upward into red shale and sandstone may indicate the maturing of a fluvial system. The predominance of red and gray siltstone in the upper part of the succession may be the result of either flooding related to the onset of transgression or overbank deposition in a fluviatile system. The presence of clean, cross-laminated orthoquartzite together with shale and siltstone in the overlying Random Formation suggests high energy, nearshore deposition, possibly as tidal sand ridges or intertidal mudflats (Hiscott, personal communication, 1981).

The Lower Cambrian sequences in the area are dominated by shale with lesser proportions of fine siltstone and shaly to massive carbonates. The lack of coarser grained clastics indicates minimal terrestrial input during this time; recognizable sedimentary structures coupled with the presence of limestone beds and nodules suggest shallow marine deposition. More specifically, the presence of oncolites within the limestone beds indicates a high energy, low intertidal to high subtidal environment.

STRUCTURAL AND METAMORPHIC HISTORY

Introduction

The structural grain of the Baine Harbour - Point Enragée area reflects the northeasterly trend of all units which has been flexured into an east-west orientation in the central parts of the area. The main phase of deformation, characteristically inhomogeneous in nature, resulted in regional northwest-southeast shortening which produced moderate to tight upright folds with associated axial-plane cleavage. Northwest-dipping reverse faults and normal faults resulted from the same compressional event. Subsequent pulses of deformation caused a regional flexuring of strike from northeast to east-west, and associated strike-slip faulting. A series of crenulations, kinks and related brittle structures reflect the latest stages of deformation.

The main period of deformation and associated subgreenschist to greenschist facies metamorphism postdates the deposition of Cambrian strata. Recent geochronological studies suggest that the main period of metamorphism associated with regional deformation occurred during the Acadian orogeny (Dallmeyer, 1980; Dallmeyer et al., in press).

Structures related to the main deformation period

Regional foliation

The regional foliation, developed in almost all rocks throughout the area, is in places axial planar to both outcrop-scale and map-scale folds, and is often coplanar with primary layering. Intensity of foliation varies from a widely spaced fracture cleavage to a penetrative schistosity; this variation is, in part, lithologically controlled. The finer grained epiclastic, immature clastic, and unwelded pyroclastic rocks commonly display a penetrative orientation of sericite and associated phyllosilicates to form a penetrative slaty cleavage and schistosity. In these rocks, folds may be rare. The coarser grained crystal tuffs and clast-bearing rocks contain an anastomosing mineral fabric, which is penetrative in the matrix but forms augen of coarser grains and clasts. The augen are flattened and elongated in the plane of the foliation. No tectonic fabric is recognizable in many of the massive rhyolite flows but concordant rhyolitic lapilli tuffs display penetrative sericitic foliation. Deformation in strongly welded ash-flow tuff is marked by local shard and lapilli rotation. Many coarse grained volcanic breccias and conglomerates display little macroscopic evidence of deformation; locally, original clast orientations remain oblique to a microscopic foliation in the matrix. The pretectonic hornfelses in the northern part of the area are generally nonfoliated. The adjacent intrusives are either massive or weakly foliated in their central parts, but are locally more intensely deformed in linear belts near their margins.

Northeast striking linear zones of relatively intense deformation, which are marked by a strong vertical or moderately west dipping schistosity, are present in the Marystown Group. The width of the zones varies from a few centimetres to several metres; some of the wider zones are traceable for up to 15 km along strike. Some such zones are related to exposed faults or fault zones; others are unrelated to brittle structures and represent ductile shear zones. The latter are best exposed in volcanic rocks of Unit 2 west of Black River in the southern part of the Point Enragée area.

Despite the inhomogeneous nature of deformation, there is an irregular increase in faulting and intensity of the regional foliation from west to east across the region, particularly near the extension of the Paradise Sound Fault. The structural contrasts across this fault are shown mainly by fold style and foliation intensity. Outcrops of Marystown Group volcanic rocks adjacent to the fault characteristically display a coplanar penetrative foliation, marked by the growth of either chlorite and/or actinolite or sericite, epidote and quartz, which is axial planar to rarely exposed tight, upright isoclinal folds. Faults and later small scale brittle structures are most common near the Paradise Sound Fault; the main orientation of faults is subparallel to the regional northeast trend.

In contrast, Musgravetown Group strata east of the Paradise Sound Fault are characteristically folded into open synclines and anticlines. Isoclinal folding is rare; relatively tight folds appear to be associated only with thrust faults at White Sail Head and within overlying Cambrian strata near Southeast Bight and on Long Island. Tectonic fabrics are widespread only in the more immature, finer grained clastics, and are generally represented only by a coarse fracture cleavage. The most marked structural contrast between these groups is best seen at Flat Islands, Placentia Bay. At this locality, polydeformed rhyolite tuffs of the Marystown Group are in fault contact with gently folded, weakly cleaved clastics and massive mafic flows of Units 7 and 2 respectively.

The above contrasts are in part the result of lithological control, but may also indicate the juxtaposition of different tectonic levels along faults with significant vertical throw. The apparent increase in strain from west to east may suggest erosion into progressively deeper levels of a major shear belt in this area.

Folds

The main deformation produced a series of moderate to tight and isoclinal folds which are either upright or overturned to the southeast. Most folds are mesoscopic and are interpreted to be parasitic on larger map-scale structures. Axial planes strike mainly northeast but are locally warped into an east-west orientation. Folds plunge in both the northeast and southwest directions and individual minor folds are in places doubly plunging.

Where developed, tight to isoclinal outcrop-scale folds are characteristic of the folding style of the poorly welded pyroclastic and related epiclastic deposits throughout the eastern two-thirds of the Marystown Group. Densely welded pyroclastic deposits and massive rhyolite and thermally metamorphosed mafic flows are rarely folded on outcrop scale.

Large scale folds occur throughout the area but are best developed in Cambrian strata and in the Musgravetown Group. The paucity of recognizable map-scale and outcrop-scale folds in much of the Marystown Group may be more apparent than real, due to noncontinuous exposure, rare primary orientations and, more importantly, the lack of lithologically unique marker units which can be traced around fold hinges. Also, rapid facies variations which occur along strike in the volcaniclastic deposits prevent correlation of lithologically heterogeneous stratigraphic units across fold hinges.

Open synclines are present in the finer grained clastics of the Musgravetown Group on Marticot Island and Long Island and on the southern parts of the Paradise Peninsula. Folds at the former two localities plunge moderately southwest while those at the latter locality plunge to the northeast. Smaller scale, moderately open to locally tight folds are parasitic on the larger structures. Southeast plunging syncline-anticline pairs in the Marystown Group and adjacent Cambrian rocks are exposed in the region between Paradise Sound and Cape Roger Bay. Similarly oriented fold pairs, up to 1 km in wavelength, are developed in Musgravetown Group and Cambrian strata on Long Island. The Cambrian strata on Jude Island are folded into upright open anticlines and synclines (Plate 19).

Broad, map-scale anticlines and related "domes" are dominant in the main outcrop belt of the Marystown Group south of the Unit 6 granitoid massifs. The wavelength of these structures varies from <1 to 5 km, whereas intervening synclines are relatively tight. The limbs of several of these folds are offset by northeast and east-west trending conjugate faults.

Faults

Most of the major faults in the region trend northeast, parallel to the regional structural trend. They include high angle reverse faults and easterly directed thrust faults and vertical or steeply dipping normal faults. North and northwest trending faults and shear zones display components of both vertical and strike slip movements. They may be either conjugate about and related to the main northwest-southeast stress direction or be related to later pulses of deformation. Minor cross-faults, spatially related to and merging into the major northeast trending structures, are genetically related to the main period of faulting. Relative displacements along the major faults in the eastern part of the Marystown Group

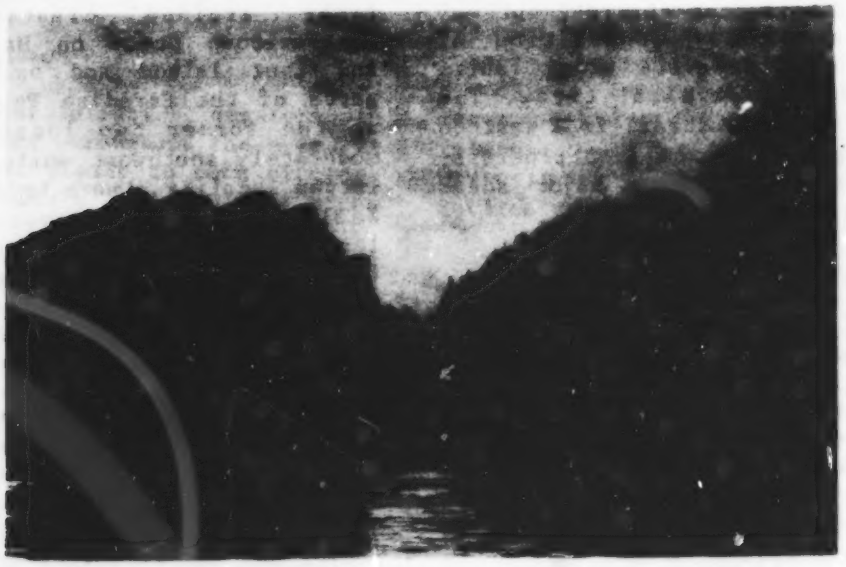


Plate 19: Open anticline in Lower Cambrian shale, Jude Island.

indicate that they were reactivated several times during the main orogenic episode.

The trace of the Paradise Sound Fault represents the most fundamental structural break in the area. This fault forms part of a 250 km long fault system including the Little Bay Fault (Strong et al., 1978b), the Charlottetown Fault (Younce, 1970), the Cottels Island Fault (Jenness, 1963) and an unnamed fault in the Sound Island and Harbour Buffett areas (O'Driscoll, 1978). Along most of its length, the fault juxtaposes deformed, greenschist facies volcanic rocks of the Marystown and Love Cove Groups to the west with weakly deformed terrigenous clastics of the Musgravetown Group and its equivalents to the east. Although earlier displacements cannot be ruled out, it appears that the major vertical movements are associated with the main period of Acadian orogenesis. Late lateral displacements postdate the regional flexure of the entire belt. The fault plane is unexposed in the present map area; however stratigraphic and structural style variations across its trace here and to the north suggest that the fault is a high angle reverse fault.

Later structures

Structures which postdate features related to the main deformational event include faults, shear zones, crenulation cleavages associated brittle and semi-brittle structures (Plate 20), and the regional flexuring of earlier structural trends. Late ductile deformation, represented by rare, outcrop-scale fold pairs which are localized in the recess of the regional flexure, are coplanar with first phase structures. Some of the northwest trending shear zones in the west-central parts of the area may be related to this episode of ductile deformation. Other northwest and northeast trending fault and shear zones represent late stage movements along first phase faults of similar orientation. Fault breccia near Grand John, containing randomly oriented

sericite schist fragments, indicates late stage brittle reactivation of ductile shear zones.

Plate 20: Kink bands in phyllites, Unit 2a of the Marystown Group.

Late strain-slip foliation locally overprints earlier cleavages and is related to northwest trending shear zones in flexure recesses. On Flat Islands in Placentia Bay, rhyolite tuff of the Marystown Group contains a well developed crenulation cleavage which is axial planar to upright, second phase folds.

The largest scale regional structure in the area is the late stage flexure of the regional foliation and Proterozoic and Cambrian stratigraphic units. Foliation azimuths approximate 045° in the southwesternmost part of the area. In the central parts of the Point Enragée area trends are typically northeast and become flexured into an east-west orientation in north-central and western parts of the Point Enragée and Baine Harbour areas respectively. The northeasternmost parts of the area are characterized by northeast trending foliation.

The regional flexuring affects the part of the Burin Peninsula south of North latitude 47°30' (O'Brien, 1979) and mimics the overall trend of the Hermitage Flexure of southern and southwestern Newfoundland (Williams et al., 1970; Brown and Colman-Sadd, 1976). The northern recess of the Burin Peninsula flexure is the locus of northwest trending semibrittle and ductile structures. The major salient of the flexure in the southern Burin Peninsula (1M/3, 1L/14) is marked by the intrusion of the Carboniferous St. Lawrence Granite, apparently along a north-south trending fault zone (Strong et al., 1978b). The granite is post-tectonic with respect to the flexuring, giving a Carboniferous upper limit for the formation of the flexure.

The nature of the mechanism by which this feature was formed is unclear; however, several possibilities exist. The sigmoidal curvature of the foliations has the form of a ductile shear zone similar to smaller scale ductile shears described by Ramsay and Graham (1970). A sinistral shear couple, parallel to the trend of the fold isogons (axial planar to the structure) could ideally modify original northeast structural orientations, and also produce northwest trending faults and shear zones in the recesses of the flexure. Molnar and Tapponier (1975) invoked a mechanism of strike-slip faulting to produce regional flexures associated with continental collision tectonics. A similar mechanism might be

applicable to the Burin Peninsula flexure, namely, a series of right-lateral movements along northwest trending strike slip faults during the final stages of the Acadian orogeny. Alternatively, the flexure may be simply interpreted as a major late orogenic fold, folding this part of the western Avalon Zone around northwest trending axial planes.

Regional metamorphism

The main deformational event was accompanied by regional metamorphism under subgreenschist to greenschist facies conditions. The metamorphic grade is related to intensity of deformation and, in part, to structural and/or stratigraphic levels with the succession. The metamorphic mineral assemblages and the degree of recrystallization are influenced by original rock compositions.

Mafic volcanic rocks of Unit 2 characteristically display a lower greenschist facies assemblage of chlorite, epidote, albite, calcite, actinolite and opaque oxides. Fine grained mafic rocks are commonly recrystallized, and contain foliated chloritic matrices, whereas the coarser grained flows retain relict igneous textures. Most of the felsic volcanic rocks and volcanogenic clastics of Units 2 and 3 display a lower greenschist facies metamorphic assemblage of sericite, quartz and epidote, whereas the overlying mafic rocks of Unit 4 were only locally metamorphosed under lower greenschist facies conditions. Deformation and metamorphism of the partially welded felsic tuffaceous deposits of Unit 2 locally resulted in the formation of sericite schist. These are typified by secondary growth of sericite, which defines the main foliation, and by varying degrees of groundmass recrystallization. Chlorite and, very rarely, brown biotite are intergrown with the sericite.

Mafic rocks of Unit 4 were metamorphosed under prehnite - pumpellyite to lower greenschist facies conditions. Flows forming the rugged hills west of Point Enragée locally contain prehnite as an amygdale-filling phase.

All phases of the granitoid massifs in the north-central parts of the map area were metamorphosed. Biotite and amphibole are typically altered to chlorite, quartz is cloudy and plagioclase is partly or completely replaced by epidote.

Thermal metamorphism

The effects of thermal metamorphism are evident, to varying degrees, around the Proterozoic granites throughout the area. The thermal aureole around the two major massifs in the north-central part of the Point Enragée area extends from several tens of metres to 2 km from the plutons' margins. The irregular cartographic distribution of the aureole is due to the cumulative effect of an undulatory roof morphology, the presence of near surface subsidiary stocks and lenses, the protolith of the hornfelses, and locally faulted pluton contacts.

The main thermal metamorphism varies from albite-epidote to hornblende-hornfels facies. Pelitic hornfelses are characterized by quartz, sericite (muscovite) and/or biotite. The growth of pre-regional metamorphic albite, epidote, actinolite and, to a lesser degree, hornblende is diagnostic of the mafic lithotypes.

Unit 2 hornfelses of a felsic volcanic protolith are pink or dark gray, fine grained, locally conchoidally fractured rocks with phenocrysts of quartz and alkali feldspar. In the coarse grained rhyolitic ash flows, recrystallization produces macroscopic saccharoidal textures. Mafic rocks in the thermal aureole vary from fine grained, dark gray or green, locally silicified rocks to coarse amphibole-

porphyroblastic hornfelses. Near the pluton margins, fine grained clastics of Unit 3 have been thermally altered to spotted slates containing andalusite and cordierite porphyroblasts. The coarser grained clastic hornfelses are pink to brown weathering, pyritized and silicified.

Age of metamorphism

The youngest rocks in the area to be affected by the regional deformation and associated metamorphic event are Lower Cambrian in age. Stratigraphic evidence for an upper time limit of deformation is lacking in the present area. However, evidence from the southern Burin Peninsula (Strong et al., 1978a,b; O'Brien, 1979) indicates that orogenesis was complete prior to the intrusion of the Lower Carboniferous St. Lawrence Granite. Therefore, on the basis of stratigraphic evidence alone, it is not possible to establish whether the deformation is related to the Virgilian (Glover and Sinha, 1973), Acadian (e.g. Williams et al., 1974) or Taconic (e.g. Rodgers, 1967) Lower Paleozoic orogenies.

$^{40}Ar/^{39}Ar$ incremental release age spectra have been determined for 10 phyllitic felsic volcanic rocks from Unit 2 and their equivalents in the adjacent Sound Island area (Figure 9). The dates determined vary from 356 $\pm$ 10 Ma to 400 $\pm$ 10 Ma, with 70% of the cooling ages lying between 380 Ma and 400 Ma (Dallmeyer, 1980; Dallmeyer et al., in press). Given the low grade character of the metamorphism, it is felt that these ages indicate the time of the last regional deformation. Small differences in age may reflect real differences in the time of cooling below argon retention temperatures (D. Dallmeyer, pers. comm., 1979). The above data strongly suggest that the main period of deformation and low grade regional metamorphism is related to Acadian orogenesis (Dallmeyer et al., in press).

TECTONIC MODELS

A variety of tectonic models have previously been proposed for the Late Proterozoic evolution of the Avalon Zone of the Newfoundland Appalachians. From these have emerged two contrasting styles of tectonic evolution. One depicts the Proterozoic rocks of the zone as having formed in an ensialic rift setting (e.g. Papezik, 1970; Strong et al., 1978a; Strong, 1979). The second utilizes the concept of arc volcanicity at a consuming plate margin. The merits and shortcomings of these models are discussed separately below. A new tectonic model, analogous with the Late Proterozoic Pan African evolution of the "Avalonian" equivalents in North Africa is proposed here. The controlling tectonic regime during the Late Proterozoic development of the Avalon Zone is considered to be transitional between intraplate and continental margin orogenesis.

Rifting or intraplate tectonics

The earliest tectonic models were based on the geology of the Avalon Peninsula. Papezik (1969, 1970 and 1972) considered the Late Proterozoic volcanics there (Harbour Main Group) to be the result of alkalic continental volcanism related to block faulting and rifting of a continental platform. Similar interpretations and analogies with the Basin and Range Province of the United States were made by Strong et al. (1974), Nixon (1974), and Strong and Minatides (1975). Strong et al. (1978a,b) proposed an evolutionary model for the Late Proterozoic succession of the southwestern Avalon Zone; it involved rifting of continental crust, resulting in continental volcanism and local rupturing of the crust to produce small tracts of oceanic crust (Burin Group). This model invoked abortion of the rifting, followed by resumption of continental style volcanism represented by the Marystown Group and its equivalents.

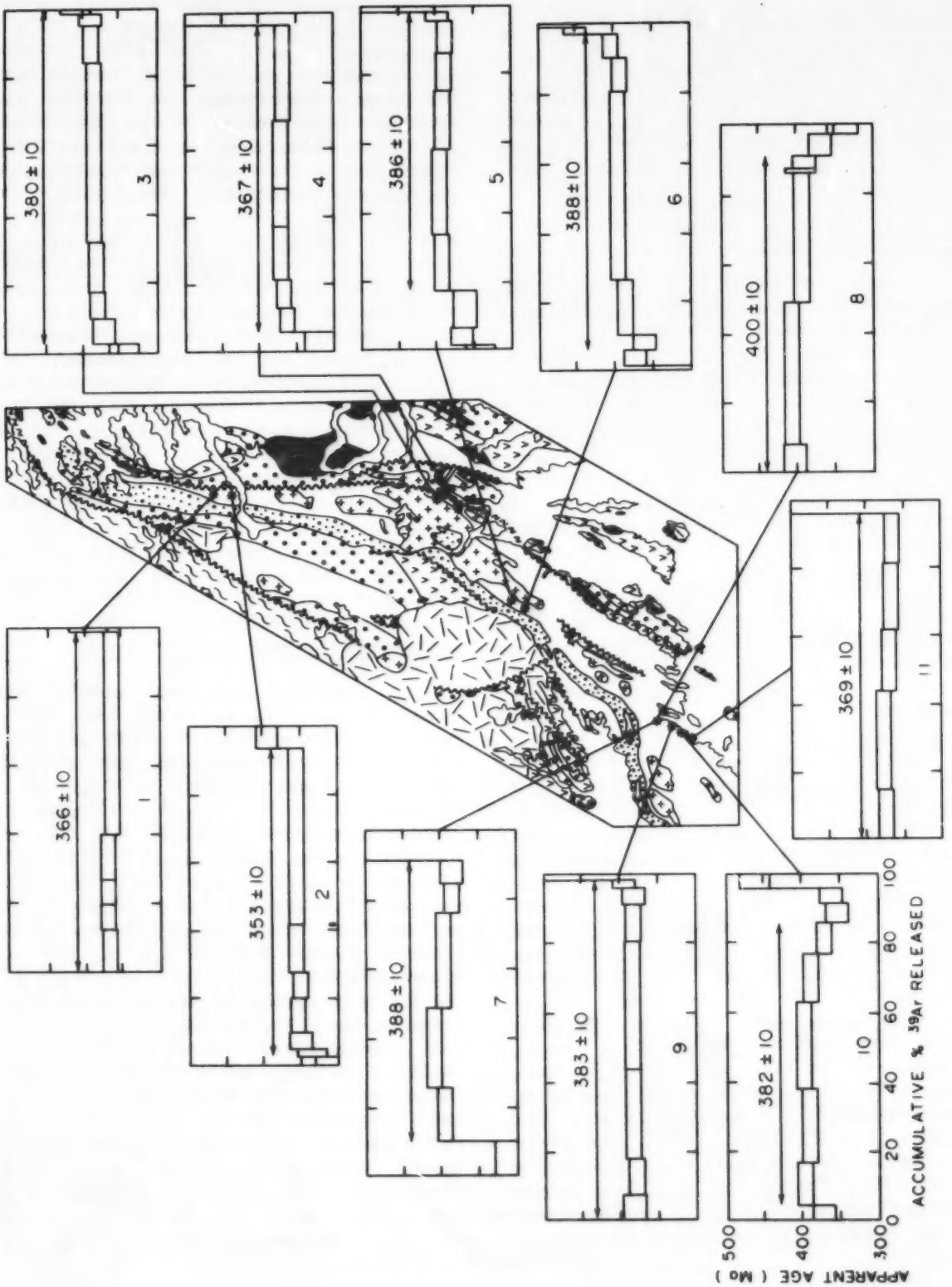


Figure 6: $^{40}Ar/^{39}Ar$ incremental release age spectra from the Marystown Group and its equivalents in the northern Burin Peninsula (from Dallmeyer et al., in press; legend for map as in Figure 4).

The rifting model led to the concept of the Avalon Zone as a precursor stage to the opening of Iapetus and a genetic relationship with the Appalachian orogen (e.g. Papezik, 1970; Williams et al., 1972, 1974). The Late Proterozoic age and bimodal nature of many of the Newfoundland Avalon Zone volcanic rocks, coupled with the continuity of the zone along the eastern margin of the Appalachian orogen may support this notion. One modern analogue of such a setting would be the Lord Howe Rise, a 2000 km long ridge of continental crust which lies in the Tasman Sea approximately 1000 km east of the present Australian continental margin. Jongsma and Mutter (1978) interpret the Lord Howe Rise as the rifted continental margin of Australia which was detached from the rest of the continent during nonaxial rifting to produce the Tasman Sea. Such a model is compatible with the Avalon Zone in terms of scale, timing and continuity within the Appalachian orogen. However, it fails to explain readily the absence of the zone in the Caledonian orogen in Scandinavia (e.g. Gee and Zachrisson, 1979). Nor does this model explain the apparent continuity of the Avalon Zone with the Late Proterozoic successions of the Pan African belts of North Africa. While the model is compatible with the Late Proterozoic volcano-sedimentary facies of the zone, it fails to accommodate adequately pre-750 Ma evolution of the zone (cf. Wardle, 1978; O'Brien et al., in press).

A second analogue for rift-related tectonics in the Avalon Zone would be the Cenozoic evolution of the North American Basin and Range Province. Modelling by various authors (e.g. Atwater, 1970; Christiansen and Lipman, 1972) relates the extensive subaerial bimodal volcanism there to drastic changes in plate motions and the initiation of transform movements between the Pacific and American plates. Early compression and related calc-alkaline volcanicity was replaced by a broad extensional regime characterized by widespread subaerial, bimodal volcanism in the Late Cenozoic. Comparisons of the Avalon Zone with the Basin and Range Province (cf. Papezik, 1970) are locally consistent with some of the volcanic facies and the petrochemical affinities of these rocks in Newfoundland. Such a model does not adequately explain the extensive development of turbidite facies in the zone, nor does it explain the chemical affinities of the volcanism elsewhere in the zone (e.g. Whitney et al., 1978). Like the Lord Howe Rise model, this analogue fails to provide an adequate framework for the pre-750 Ma evolution of the zone.

Compressional tectonics: ensimatic or ensialic arc

The earliest proponents of compressional tectonics in the Late Proterozoic evolution of the Avalon Zone were Hughes and Brueckner (1971). They interpreted the geology of the Avalon Peninsula in terms of a volcanic island arc complex, which was active until Latest Proterozoic times. Their depositional model involved penecontemporaneous volcanism and marine to terrestrial sedimentation.

Compressional tectonic models for the Proterozoic evolution of the Avalon Zone were also invoked by various workers elsewhere in the Appalachian orogen (e.g. Rast et al., 1976; Whitney et al., 1978; Skehan and Murray, 1980). In essence, their models suggest that the Proterozoic volcanism and plutonism was related to subduction of oceanic crust under some form of "Avalonian" continental block with the subsequent formation of either an ensialic volcanic arc or a primitive oceanic island arc.

Such models relate the volcanism and plutonism directly to the subduction of oceanic crust, and in doing so, imply that the Late Proterozoic successions of the Avalon Zone formed at a consuming plate margin during the ocean closure phase of a Wilson cycle. A major problem

arises with the apparent lack of extensive andesitic volcanism in the Avalon Zone in Newfoundland. This suggests that extensive subduction of oceanic crust was not a major factor in Proterozoic evolution there. If indeed there was even limited subduction, timing constraints from western Newfoundland indicate that this crust was not related to the Iapetus ocean. Any consuming plate margin or island arc model requires that Avalon Zone development occurred prior to 600 Ma and was thus unrelated to subsequent Appalachian development, at least until Siluro-Devonian orogenesis and the closure of Iapetus (cf. O'Brien et al., in press).

"Pan-African" tectonics

Fundamental to the modelling of Proterozoic "Avalonian" tectonics is the recognition of the global extent of the Avalon "zone" successions. The Late Proterozoic evolution of the Pan-African equivalents of the Avalon Zone in North Africa has important ramifications in modelling tectonics of the North American example (see O'Brien et al., in press).

Proterozoic orogenesis in the Avalon Zone may have been the result of a tectonic regime transitional between intraplate rift (cf. Strong et al., 1978a; Strong, 1979) and continental margin orogenesis (cf. Rast et al., 1976), similar to that evoked by Kroner (1979, 1980), Martin and Porada (1977), and others for the Late Proterozoic Pan-African belts of North Africa. The overall similarity in age, lithology and tectonic history between the Avalon Zone of the Appalachian orogen and the Pan-African belts suggests that they were continuous, and that all evolved in similar tectonic conditions (O'Brien et al., in press). Kroner's (1979) model interprets the Pan-African belts as the result of repeated attempts of a continental mass to break apart during the Late Proterozoic; the model may be extended to include the Proterozoic successions along the eastern margin of North America. It is suggested that wide variations in stages and degrees of intracratonic crustal mobility occurred along the arcuate extent of these belts. These variations are inherently related to whether the "orogen" initiated as an upper crustal graben, a deep ensialic basin, or more rarely as an ocean with a well defined continental margin (Kroner, 1979). Only where ocean basins formed does the Wilson cycle play a role in orogenesis and even then, rarely was the rifting extensive enough to allow subduction, continental collision and associated deformation and metamorphism (Kroner, 1979, 1980).

A tectonic model for the Proterozoic evolution of the Canadian Avalon Zone has been developed by O'Brien et al. (in press) and is schematically portrayed in Figure 10. Development began between 1000 Ma and 800 Ma with initial attempts to rift a pre-Pan-African/Avalonian continental basement. During this time totally ensialic flysch basins were formed (Figure 10a) and the carbonate-clastic Green Head Group (Wardle, 1978) of the Avalon Zone of southern New Brunswick was deposited (Figure 10b). Continued attempts at rifting, in the form of ductile spreading of the lower crust and upper asthenosphere over zones of high heat flow, locally resulted in partial melting and high grade metamorphism of the carbonate-clastic sequence represented by the Green Head Group and its equivalents in the Avalon Zone of Nova Scotia (Figure 10c). This event, not recognized in Newfoundland, was followed, or possibly accompanied, by local complete crustal separation with the formation of oceanic crust, such as the Burin Group (Figure 10d). This period of ensialic rifting may have been long-lived. The oceanic crust may be the result of delamination of the lower crust (cf. Martin and Porada, 1977). This process involves gravitational instability produced by stretching and thinning of the lower crust, resulting in detachment or delamination of dense mantle lithosphere

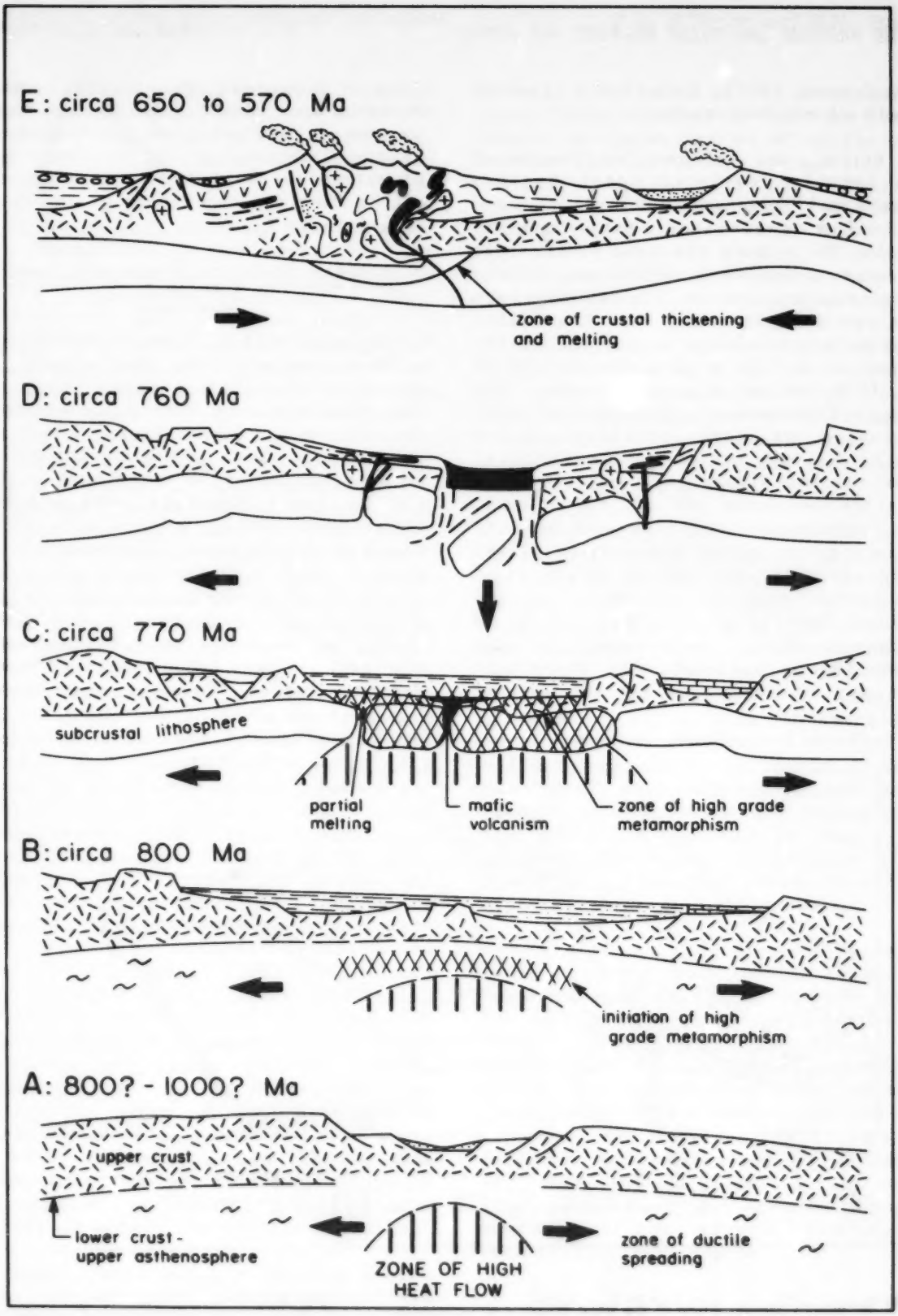


Figure 10: Schematic model for the Proterozoic evolution of the Avalon Zone in the Canadian Appalachian orogen (from O'Brien et al., in press).

(cf. Kroner, 1979), formation of limited tracts of oceanic crust.

Rifting was followed by closure of the locally developed ocean basins, local and limited subduction, and collision associated with crustal melting to produce the Late Proterozoic volcanic assemblages represented by the Marystown Group and its equivalents (Figure 10e). Evidence from the Avalon Zone in New Brunswick suggests that the volcanism initiated as early as 750 Ma ago (O'Brien et al., in press). This stage of orogenesis terminated with intrusion of late granites, block faulting, and marine to terrestrial clastic deposition as seen in the Musgravetown Group and its equivalents. The widespread turbidite and pelagic sedimentation in the lower parts of the group coincided with waning volcanism. A southward prograding delta marked initial shoaling of a marine basin as is evidenced in the upper parts of the group. Early mud and sand deposition gave way to sands and gravels derived from a mountain front. The Latest Proterozoic - Early Paleozoic is marked by peneplain development, transgression of the Cambrian sea and the deposition of extensive shaly sequences diagnostic of the Cambrian succession of the Avalon Zone (Figure 11).

MINERAL OCCURRENCES AND EXPLORATION POTENTIAL

Historically, the central and northern parts of the Burin Peninsula, including the present study area, have been considered to have a low potential for economic mineralization. The only recorded exploration activity in the present map areas includes work carried out by Radex Minerals, Serem Ltee., (Schrijver 1972, 1973) and Allied Chemical Corporation (Fitzpatrick and Howse, 1973). These programs, which involved reconnaissance stream sediment sampling, prospecting and some geological mapping, were restricted by the lack of available geological maps for the region. Some of the projects

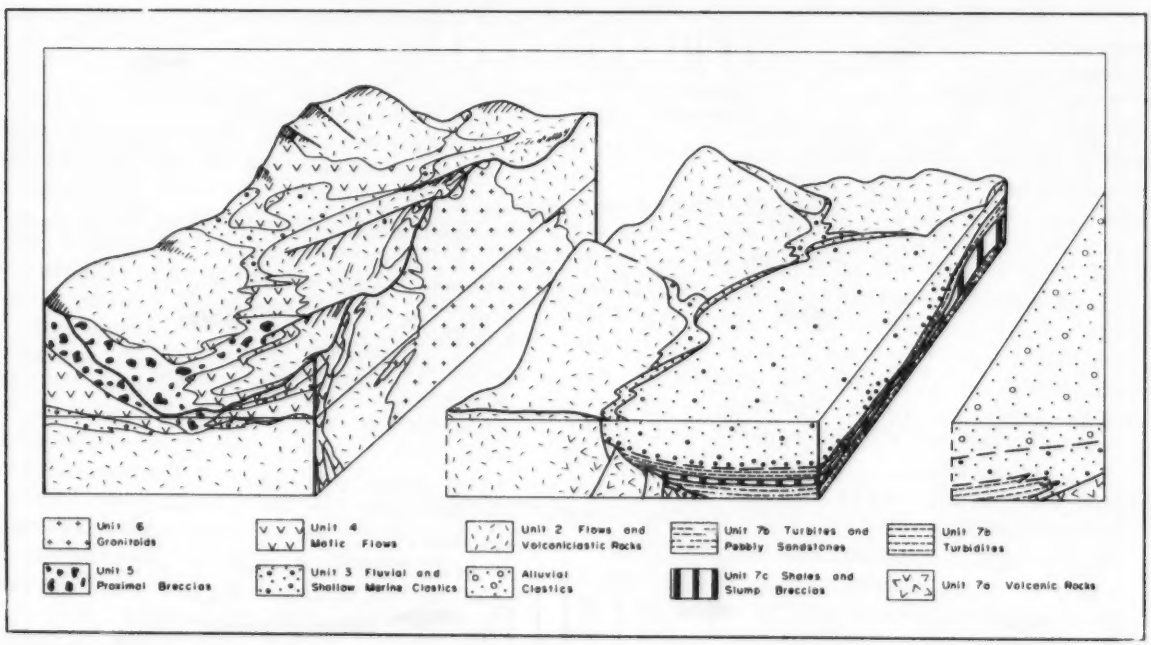

Unit 6 Granitoids
Unit 4 Mafic Flows
Unit 2 Flows and Volcaniclastic Rocks
Unit 7b Turbites and Pebbly Sandstones
Unit 7b Turbidites
Unit 5 Proximal Breccias
Unit 3 Fluvial and Shallow Marine Clastics
Alluvial Clastics
Unit 7c Shales and Slump Breccias
Unit 7a Volcanic Rocks

Figure 11: Schematic representation of the latest Proterozoic paleogeography and depositional environments in the study area.

were successful in outlining several base metal anomalies over granitoid and volcanic rocks, but, where documented, limited follow-up work was apparently discouraging.

A number of minor sulfide showings were found during the course of the present investigation. These occurrences can be generally subdivided into stratiform copper and base metal vein styles of mineralization; their host rocks are mainly mafic lavas and felsic volcaniclastics of Unit 2 of the Marystown Group.

Copper mineralization consisting of bornite, covellite, and chalcopyrite occurs as disseminations and narrow veinlets associated with chloritic shear zones in subaerial basalt flows (Unit 2b) in the west-central part of the Baine Harbour area. Minor native copper and associated copper sulfides occur in flat-lying subaerial flows on Oderin Island (Williamson, 1956; O'Brien, 1978). Mineralization occurs mainly as small (<1 mm) flecks in prehnite-filled amygdales, chloritic shear zones and quartz and quartz-prehnite-epidote veins. In all of the above showings the mafic rocks are epidotized and display prehnite-pumpellyite transitional into lower greenschist facies metamorphic assemblages. Despite the small and uneconomic character of the known showings, their marked similarities with the Keweenawan copper deposits of Michigan (e.g. White, 1968) may indicate that the mafic sequences are potentially favourable exploration targets for similar deposits related to low grade metamorphism (cf. Jolly, 1974). Important factors in evaluating the exploration potential of these basalt units are their thicknesses (e.g. scale of mafic volcanicity) and the related transitions from prehnite-pumpellyite to greenschist facies metamorphic conditions within the mafic succession.

Small, base metal - bearing quartz veins and stringers cutting sericitized felsic pyroclastics of Unit 2 outcrop in several localities in the Baine Harbour area. These showings are of very limited extent and appear to be of little or no commercial importance. One of the largest of these is in a Route 11 roadcut in epidotized and sericitized, banded rhyolite near Baine Harbour; it contains several blebs of massive chalcocite in faulted quartz veins from 1 to 15 cm thick which crosscut the regional sericitic foliation. Other minor showings consist of flecks of galena, covellite, pyrite and malachite in narrow quartz-carbonate stringers. The mineralization may be the result of either metamorphism and associated ductile deformation or the intrusion of subvolcanic porphyries.

Epigenetic vein mineralization occurs within the Marystown Group along the margins of the granitoid intrusions in the north-central part of the map area. Specular hematite is the main metallic phase in the showings; they are spatially and genetically related to granitic intrusion and may be metasomatic in origin. Galena-bearing quartz veins cutting volcanic and sedimentary rocks of Units 2 and 3 immediately east of Point Enragée may be related to the subsurface extension of the granitoid massifs in that area. Galena-quartz veins in granite float, discovered near the latter locality, assayed 59 ppm Ag and 0.1 ppm Au.

Extensive pyritiferous gossans, exposed in several localities in the Point Enragée and Baine Harbour areas, are spatially related to fracture and shear zones in silicified and sericitized felsic volcanic rocks of Unit 2. The potential of these and other fault zones in the western Avalon Zone as prospective exploration targets for gold has been discussed by Taylor et al., 1979, and the reader is referred to this publication for a more detailed summary of the mineral exploration potential of this region.

The potential for uranium mineralization in the area remains

unproven. Reconnaissance scintillometer surveys of much of the region during the course of the study revealed slight systematic variations in background radiation, but failed to outline any significantly anomalous areas.

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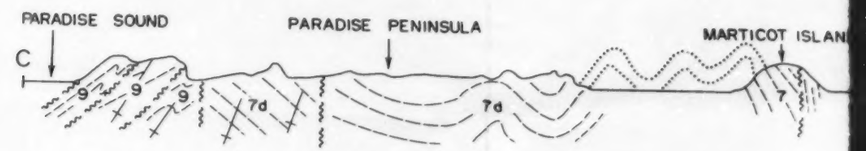
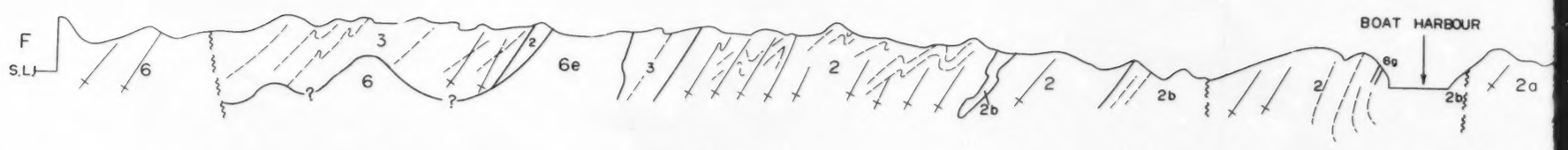
STRUCTURAL CROSS-SECTION
OF THE
BAINE HARBOUR AND POINT ENRAGÉE

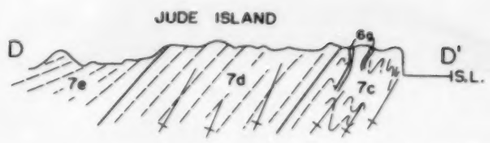
Lines of section are located on map 83-34 (AA' to GG') and map 83-3

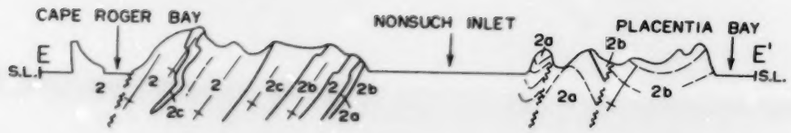


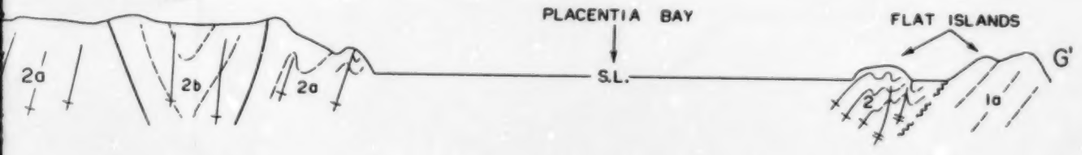


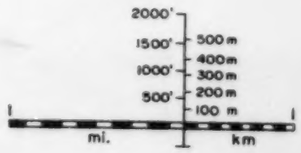
AL CROSS-SECTIONS
OF THE
D POINT ENRAGÉE MAP AREAS

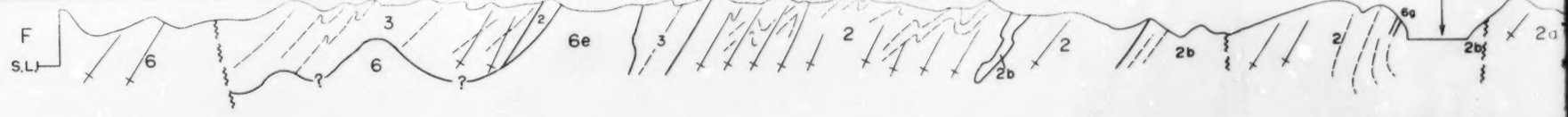
map 83-34 (AA' to GG') and map 83-35 (HH' and II')

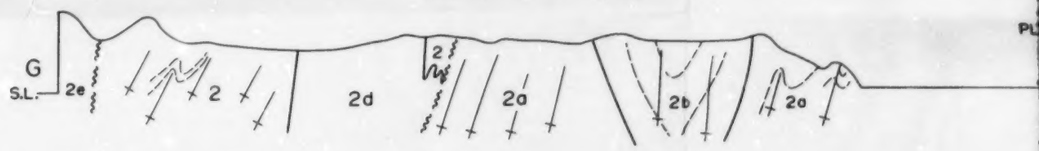


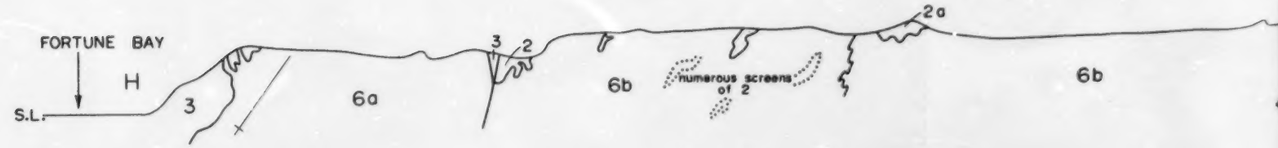


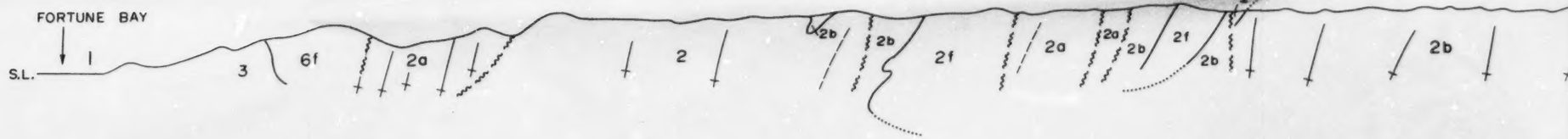






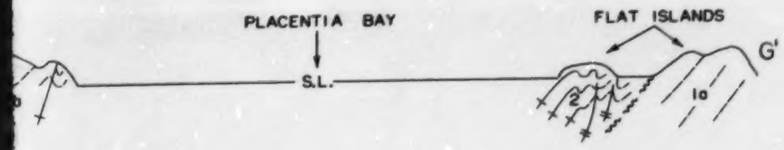


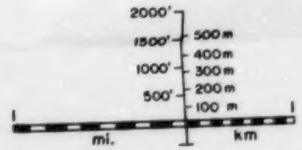


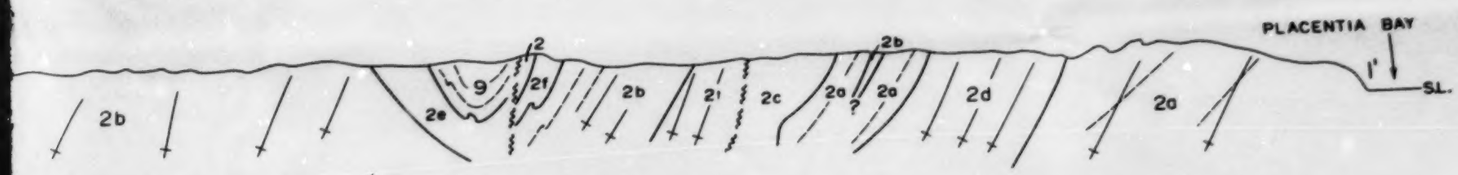


KEY

Topographic Surface		Geological Contact	
Fault		Bedding	
Schistosity (1st generation)		Schistosity (2nd generation)	







tact

nd generation)

POOR

QUALITY

ORIGINAL